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**PIPES FOR HEAT: SIMPLE DEVICES  
TRANSFER ENERGY & ADJUST TO DEMAND  
-- WITH NO MOVING PARTS**

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As heat transfer requirements become more critical in aerospace, electronics, industrial and other applications, engineers will increasingly turn to a relatively simple device that has no moving parts and can adjust to heating or cooling demands by itself, a Georgia Tech professor predicts.

Heat pipes already help cool footings for the Alaskan Pipeline, keep advanced electronic components from overheating, and may one day help the National Aerospace Plane soar at hypersonic speeds.

"As time goes on, our equipment will have more intense heating and cooling requirements, so there is a growing need for equipment like heat pipes to handle very high heat fluxes," said Dr. Gene Colwell, professor of Mechanical Engineering at the Georgia Institute of Technology. "As we come up with new schemes for transforming energy, I think heat pipes will play a role because they do not require any pump or motor to move energy."

A heat pipe is little more than a closed tube, its walls made of conductive material and its inside lined with capillary structures similar to window screening. All gases are removed from the tube and enough "working fluid" is added to fill the capillary structure.

With one end of the pipe in a hot area and the other end in a cool area, heat will begin to flow from the heated end to the cool end at a rate much faster than it could be carried by ordinary solid conductors.

The heat pipe relies on simple laws of physics to transfer energy. At the hot end of the tube, the working fluid absorbs heat and vaporizes. The heated vapor then moves toward the cooler end, where it releases the heat and condenses back to liquid on the cooler walls of the tube.

Because the walls are covered with capillary material, the fluid is drawn back toward the heated end, pulled by capillary action just as molten wax moves up a candle wick.

"One of the nicest things about the heat pipe is that it doesn't require a pump or any external connection," Colwell added. "It's all self enclosed."

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Because of tight limits on energy available for air conditioning, spacecraft have long used heat pipes to help dissipate excess energy from crew cabins. In the Alaskan Pipeline, heat pipes transfer the chill of winter into the footings around support structures, helping them stay frozen during warmer months.

And because its passage through the atmosphere will generate high temperatures, the National Aerospace Plane (NASP) may use heat pipes along with other cooling techniques to remove heat from the leading edges of wings, engines and control surfaces. The Space Shuttle uses heat-resistant materials to counter the temperatures, but heat loads for the NASP are expected to be substantially higher than those encountered by the Shuttle.

Colwell believes heat pipes will be used more frequently in the future to cool tightly-packed aircraft electronic components, to remove heat from mechanical seals and bearings, to recover heat from powerplant exhausts -- and even to cool superconductors from the inside.

"The heat pipe may allow us to do some things we can't do now, because of its ability to smooth out temperature fluctuations and because it can handle very high heat loads," he said. "The market for heat pipes is really growing."

Because the heat pipe must vaporize its working fluid to operate, the fluid must be carefully chosen to match the temperatures at which it will operate. Low temperature applications can use a conventional refrigerant such as a freon or nitrogen. Room temperature applications may use water or ammonia, while higher temperatures require oil, mercury or even a molten metal such as sodium.

Since the working fluids operate within a fairly narrow range of temperatures, the heat pipe can be designed to transfer energy only when needed.

"If you wanted to maintain an area at a constant temperature, you could choose a working fluid that would vaporize at temperatures slightly higher than those you needed," explained Colwell. "The heat pipe wouldn't do any cooling until you reached its design temperature. As the heat load went up, the amount of vapor flow and liquid flow would go up to adjust for that."

In the past, material compatibility problems plagued the heat pipes and limited their service lives. Colwell believes engineers now understand those problems and know how to prevent them.

Still, heat pipes may be more costly than other cooling methods, and they can be difficult to use with complex geometries. "In a lot of applications, the heat pipe shows a lot of promise, but there are also a lot of applications where it doesn't fit at all," Colwell noted.

Georgia Tech has developed computer models and simulations to help engineers integrate heat pipes into structures and choose the most appropriate materials, configurations and working fluids.

"We develop tools that designers can use," Colwell explained. "We have mathematical models and computer programs that determine the effect of changing the thickness of the heat pipe wall, the material or the length of the cool section."