HEAT PIPE IMPACT ON DEHUMIDIFICATION, INDOOR AIR QUALITY AND ENERGY SAVINGS

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TENTH SYMPOSIUM ON IMPROVING BUILDING SYSTEMS
IN HOT AND HUMID CLIMATES
MAY 13-14, 1996
FT.WORTH, TEXAS

ABSTRACT

Heat pipe impact on our ability to dehumidify, protect, and improve our indoor air quality and save energy in our building systems is tremendous. Projects all over the world in hot and humid climates are using heat pipes in both slab and wrap around configurations for dehumidification, precooling, reheating and heat recovery.

BACKGROUND AND OVERVIEW

The use of heat pipes dates back to the turn of the century. Heat pipes, also termed Perkins pipes, are heat transfer devices which work by means of evaporation and condensation of a working fluid using gravity or a wicking material in a closed system.[1] At the evaporator end of the heat pipe energy is absorbed and flashes a working fluid to vapor which rapidly moves to the opposite or cool end and condenses liberating the heat energy.

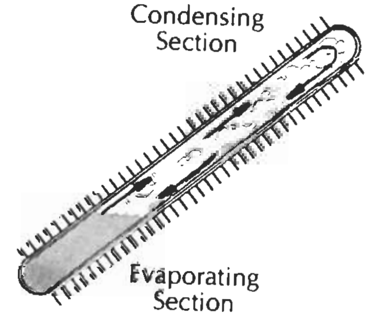

FIGURE 1. A SIMPLE HEAT PIPE

This liberates the energy and the condensate rapidly moves by aid of a wick to the evaporator area and the cycle continues as long as a difference in temperature between the evaporator and condenser areas exist.

In 1897, Perkins pipes -- unwicked, gravitational flow, heat pipes were used in the bread making industry. R. S. Gaugler, in 1942, was the first to propose that heat pipes be used in refrigeration. NASA, since the mid 1960's, has used heat pipes in aerospace applications for environmental management ranging from the early unmanned satellites up to and including the new international space station "Freedom".

Heat pipes are simple passive devices that transfer thermal energy using no moving parts with very little heat loss. The many forms of heat pipe devices are very adaptable and can operate up to 3000 degrees Kelvin and in such extremes as high electromagnetic fields and weightlessness.[2] They have a very high heat conductivity effectiveness from several hundreds to thousands of times greater than that of copper and silver.[3] Evaporative thermosyphon heat pipes act as thermal diodes, transmitting energy in only one direction. This property can be very advantageous. The heat pipe is essentially an isothermal system, very little temperature difference is needed to drive the heat pipe.

ENVIRONMENTAL MANAGEMENT USING HEAT PIPES

Heat pipes are very useful for heat recovery applications and became a substantial market due to escalating costs during the 1970's energy crisis period. This market is starting to grow again and heat pipe heat recovery has been applied to waste heat ranging from flue gases of power plants to jet turbine exhaust. Large quantities of fresh air for buildings housing: schools, restaurants, hospitals and laboratories have been retrofitted with heat pipes for heat recovery.

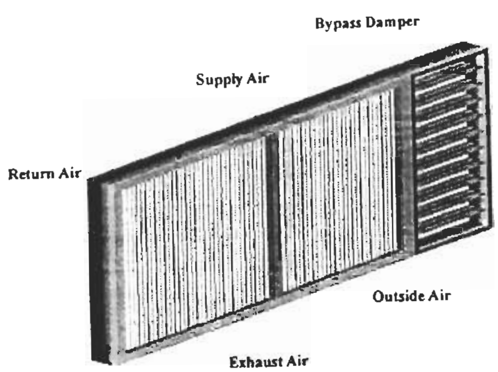

FIGURE 2. HEAT RECOVERY HEAT PIPE WITH CONTROLLABLE DAMPER

Heat pipes have the distinct advantages of being compact and are easy to clean. Unlike desiccants and heat wheels, heat pipes have **NO** cross contamination of air streams which is quite important for laboratories and hospitals.

A Vietnamese inventor named Khanh Dinh, worked with NASA Kennedy Space Center to perfect the use of heat pipes in air conditioning to passively provide precool and reheat. In 1984, he received recognition from NASA for his work with heat pipes, specifically for dehumidification in air conditioning.[4] Dinh built a portable dehumidifier machine for the space shuttles that uses two sets of heat pipes to cool and dehumidify the ambient air. It delivers this air to the shuttle at 6 psi., keeping the thermal tiles dry while the shuttle is on the ground in humid conditions.

FIGURE 3. SPACE SHUTTLE TILE DEHUMIDIFIER

Dinh holds eight patents concerning HVAC and heat pipes in air conditioning for hot climates, dry climates and air exchange. Dinh's ideas, designs and manufacturing methods led to economical heat pipe production techniques, resulting in several thousand installations of dehumidifier heat pipes in HVAC. Homes, grocery stores, schools, office buildings, hospitals, hotels, restaurants, museums, archives, food processing plants, as well as many large commercial and industrial applications are using dehumidifier heat pipes.

Dehumidification can be accomplished by several methods, such as: desiccation, overcooling and reheating, and combinations of these strategies. By using heat pipes with air conditioning to dehumidify; a significant amount of energy can be saved over traditional methods. Before heat pipe utilization, traditional forms of reheat added heat to the space. Heat pipe reheat uses energy already within the space to passively accomplish the same job. This allows for the downsizing of air conditioners because they do not have to overcome the heat injected to the space as reheat, as with conventional systems. Long life and little required maintenance is inherent with heat pipes because they are simple in design and constructed of strong, durable materials, and have **NO** moving parts.

In the last several years, concerns about conservation of energy, as well as new energy codes, have given birth to a generation of buildings whose envelopes are extremely tight and well insulated. With air locks, improved weather stripping and windows which cannot be opened, it is not unusual for a new building to have less than 0.2 air changes per hour. If such a building is inhabited, mechanical ventilation is a necessity. Building envelopes are much better insulated with the new construction materials, especially sun-reflective glass, and could have one-third the sensible heat gain of an older building of the same size. The lighting systems which traditionally generated a large amount of sensible heat have been greatly improved with more energy efficient lamps producing only a fraction of the heat.

These improvements only reduce the sensible heat gains, not the latent heat gains. As a result, modern buildings might have a sensible heat ratio as low as 50 or 60%. With such a load, conventional air conditioning equipment cannot physically meet the requirements without the use of reheat. For energy conservation reasons, reheat systems are often shut off, creating very humid indoor conditions. Such humid conditions, in time, create health, environmental and maintenance problems. The increased moisture promotes mold, mildew, bacteria, spores and viruses in the air which make people sick; supply registers rust and drip with condensation, wall paper peels off, and the decaying carpets produce unpleasant odors.

In the humid regions of the world, the problem of humidity is worsened by ventilation: fresh air brought in from outside could carry 100% latent heat. Regenerative heat-exchangers are almost useless.

The method most often used is to mix fresh air with return air and let the building leak out the excess without any attempt to recover the cooling. This proves to be very energy costly!

The other solution is to use reheat: by over-cooling then reheating the air, just about any condition can be satisfied, but at what price? The big drawback is energy consumption. You first pay for the reheat energy, then you remove it by the air-conditioning system, consuming energy twice. Even when the reheat energy is free, as with hot gas recovery systems, you must still use energy for the air conditioner to remove the reheat BTUs.

In order to lower energy consumption, one of the most common approaches is to raise the chilled water temperature, turn off the reheat and close all fresh-air intakes. Not considering possible code violations, such practices are guaranteed to degrade property, equipment nd indoor air quality. High humidity (above

70% RH) will allow mildew and molds to grow in the duct work system and produce spores, which are blown over the entire conditioned area, creating allergic reactions and other afflictions such as asthma, watering eyes and sinus infection. When these "cost cutting" strategies are performed at the expense of air quality and comfort, the savings might be completely offset by losses in property damage, mental and physical health problems, and diminished personnel performance. This strategy has proved to be very flawed in this litigious era! One sick building syndrome lawsuit could outweigh, by orders of magnitude any operational savings.

A good passive heat pipe heat exchanger can save the energy used for reheat and extra cooling. The reheat energy is taken from inside the conditioned space instead of adding heat energy from outside the conditioned space as we do with other forms of reheat. Heat pipes are capable of working under very small differences of temperature and are passive devices. Heat pipes often cost less than the reheat equipment they replace and associated increase in the size of cooling plant not to mention the consumption of energy avoided!

The dehumidifier heat pipe is available in monoflat or slab configurations for mounting in ductwork.

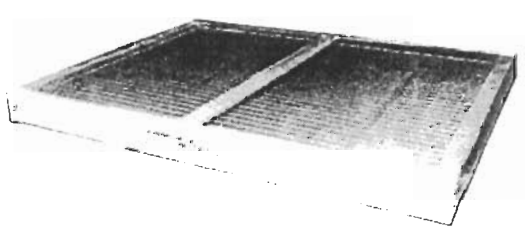

FIGURE 4. MONOFLAT OR SLAB HEAT PIPE

A very popular and efficient style of heat pipes applied to air conditioning and dehumidifiers is the wrap around configuration to be mounted around the DX or chill water cooling coil.

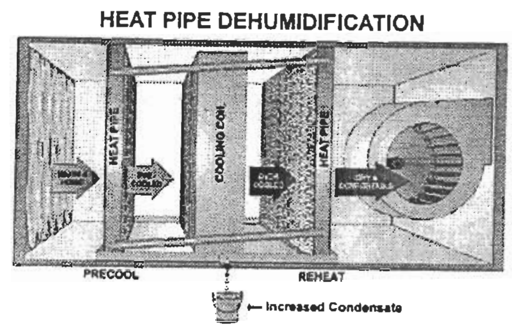

FIGURE 5. WRAP AROUND HEAT PIPE

The heat pipes can be retrofitted to existing equipment as well as new. The air conditioners size can range from a small package terminal air conditioner (PTAC) used in "through the wall" hotel applications to fan coil units to air handlers of all sizes up to multi hundred ton built up units. For heat pump applications, a desirable property of heat pipes of conducting heat only one way (thermal diode), is an advantage for winter operation.

In a building with a high sensible heat ratio, where ideal conditions are already obtained and where no extra dehumidification is needed, heat-pipes can still be used for energy savings because they allow the design engineer to raise the operating temperature of the cooling coils to obtain higher thermodynamic efficiencies: chillers can operate at 50^{o}F, rather than 42^{o}F.

Heat-pipes can also be used in treating fresh make-up air. In humid and hot climates, one of the biggest problems in bringing fresh air into a building is the latent heat the fresh air carries with it; in fact, there are times when the outdoor air is cooler than indoor (such as after a rain shower), and all the load from the outdoor air is latent. In such an application, heat-pipes can greatly improve the dehumidification of the fresh air make-up system.

One special problem encountered in hot and humid climates is the air-conditioning of schools, laboratories, smoking lounges, restaurants and hospital operating rooms: the requirement for ventilation in many cases is so high that the capacity of the fresh air make-up system exceed the load of the building. As a result, the indoor conditions of the building drift toward the conditions of the supply air from the fresh-air system, which is usually very cold and near saturation. The May 1984 Edition of the"***Trane Air Conditioning Manual***" makes it clear that neither return air by-pass or fresh-air by-pass or any kind of mixing can resolve such a situation. Some source of energy is needed for reheat to obtain more comfortable temperatures. If a heat-pipe is used to transfer heat from the warm fresh air intake to the cold supply, not only is the reheat obtained free, but the fresh air gets substantial pre-cooling effect from the heat-pipe saving on the cooling energy required.

CONCLUSION

The use of heat pipes for environmental management are a very cost effective, logical and environmentally sound strategy. Heat pipes are "GREEN MACHINES"!; they are SIMPLE, PASSIVE devices requiring no fossil fuels and use no Ozone depleting CFCs. They can help us obtain a more sustainable life style. NASA, The U.S. Department of Energy, The Electric Power Research Institute, The Department of Defense, and the Edison Electric Institute have all promoted and recognized the impact HEAT PIPES CAN have on ENERGY USAGE IN THE UNITED STATES. Several leading utilities have initiated incentive programs to encourage the use of heat pipes to replace electric reheat, and other types of reheat to efficiently dehumidify without consuming our valuable fossil fuels. Several large chains of fast food restaurants hotels and supermarkets have installed heat pipes throughout the U.S. to better environmentally manage with. On a global scale, heat pipe installations are occurring in several other nations.

In the near future I predict heat pipes will be integrated into many diverse types of products and equipment such as refrigeration, air conditioning, laundry equipment, medical devices, power systems, and microelectronic devices. **HEAT PIPES will continue to become a very useful tool to benefit and achieve DEHUMIDIFICATION, HEALTHY INDOOR AIR QUALITY AND ENERGY SAVINGS in our BUILDING SYSTEMS.**

HEAT PIPE APPLICATIONS

Heating	Cooling	Temperature Control
air conditioning reheat thermal recovery units	air conditioning precoolers fusion reactor cooling	crystal oscillator ovens black body radiation cavities
hot water and space heating from flue-gas, fireplaces	electric motors, transformers underground transformers	inertial guidance gyros telescopes, optical eqpt.
industrial process heat recycle utility boiler preheater	switchgear, circuit breakers, starters, generators, molds	electroplating baths steam baths, heat treating
aircraft wing deicing	electric bus bars, fuel cells	electronic components
solar energy collectors warming carburetors & intakes	die cooling, lathe tools dehumidifiers, disc brakes	carburetors, air intakes surgical cryoprobe
geothermal energy recovery	electronic rack cooling	batteries, fuel cells
Sterling engines, Brayton cycle engines	high density packaging thermionic converter	rotor blades, laser tuning isothermal electronic mounts
air preheaters, defrosters heat recouperators	power rectifiers, drills motorcycle crankcase cooling	isothermal furnaces, semiconductor, cryogenics
deicing highway bridges, intersections, walkways	high power electron tubes space suit temperature control	spacecraft structures, Infra-Red detector cooling
airport taxi and runways bread ovens, brick kilns	refrigerator and heat pump	black-body radiation cavities

HEAT PIPE MAJOR REFERENCES

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