TYPE 689: HEAT PIPE

General Description

Type689 models a passive device called a heat pipe, which transfers energy from one fluid stream to another - often times the same fluid stream but with a heating or cooling device inserted between the two heat exchangers of the heat pipe. Heat pipes are commonly used in dehumidification applications where warm humid air is cooled to near its dew point using the heat pipe, then is further cooled and dehumidified in a dehumidifier, then is passed back across the other end of the heat pipe where it is reheated using the heat removed from the first cooling in the heat pipe.

Nomenclature

$\dot{m}_{air,1}$	[kg/hr]	The mass flow rate of air entering stream 1
$\dot{m}_{air,2}$	[kg/hr]	The mass flow rate of air entering stream 2
$P_{out,1}$	[atm]	The absolute air pressure at the outlet of stream 1
$P_{in,1}$	[atm]	The absolute air pressure at the inlet of stream 1
ΔP_1	[atm]	The pressure drop of air across stream 1
$P_{out,2}$	[atm]	The absolute air pressure at the outlet of stream 2
$P_{in,2}$	[atm]	The absolute air pressure at the inlet of stream 2
ΔP_2	[atm]	The pressure drop of air across stream 2
$C_{\min}$	[kJ/hr.K]	The minimum capacitance air stream.
$Cp_{air,1}$	[kJ/kg.K]	The specific heat of air in stream 1
$Cp_{air,2}$	[kJ/kg.K]	The specific heat of air in stream 2
$\dot{Q}_{air}$	[kJ/hr]	The energy transferred by the heat pipe.
ε	[0..1]	The effectiveness with which the heat pipe transfers energy
$T_{air,in1}$	[ºC]	The temperature of air entering stream 1
$T_{air,in2}$	[ºC]	The temperature of air entering stream 2
$h_{air,in1}$	[kJ/kg]	The enthalpy of air entering stream 1
$h_{air,in2}$	[kJ/kg]	The enthalpy of air entering stream 2
$h_{air,out1}$	[kJ/kg]	The enthalpy of air exiting stream 1
$h_{air,out2}$	[kJ/kg]	The enthalpy of air exiting stream 2

Detailed Description

Heat pipes can be used in applications ranging from HVAC to solar thermal systems. A heat pipe is nothing more than a sealed device containing refrigerant. Each end of the device is subject to a fluid stream, whether air or a liquid. At one end of the device energy is absorbed from the fluid stream and the refrigerant boils, turning to vapor. At the other end of the heat pipe, the fluid stream cools the refrigerant vapor, turning it back to a liquid. Obviously for a heat pipe to work, the two fluid streams cannot be at the same conditions. As was mentioned in the General Description section, the two fluid streams are

often different regions of the same stream and the heat pipe is used to enhance the performance of a heating or cooling device located between the two ends of the heat pipe by preheating or precooling inlet air. Another common heat pipe application is in the solar thermal field. One end of the heat pipe is subjected to solar radiation using an absorber plate. Solar energy boils the refrigerant, which rises to the top of the heat pipe that may be immersed in a water stream. The water stream absorbs energy from the refrigerant, reliquifying it, whereupon it drains back to the end that is subject to solar radiation. In all cases, heat pipes must be configured in such a way that vaporous refrigerant can travel from the boiling end to the cooling end of the heat pipe and in such a way that liquid refrigerant drains from the cooling end back to the boiling end. Type689 models a heat pipe that is subject to two air streams which may or may not be connected. The Type689 heat pipes is shown schematically in Figure 1 in which refrigerant boils at the "A" end and is reliquified at the "B" end. For the purposes of Type689, the air stream flowing across the "A" end of the heat pipe in Figure 1 will be referred to as air stream 1 and the air stream flowing across the "B" end of the heat pipe in Figure 1 will be referred to as air stream 2.

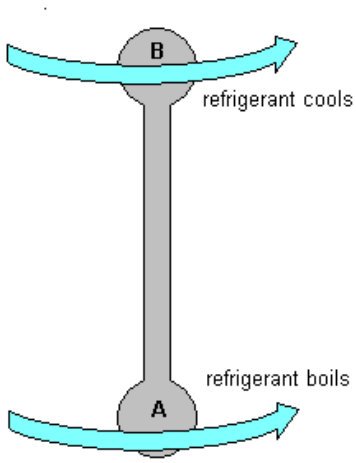


Figure 1: Heat Pipe Schematic

Each time Type689 is called, it fully determines the inlet air state of each of the two air streams. The TRNSYS Psychrometrics routine is called with pressure, temperature, and either relative humidity or absolute humidity ratio (depending upon the value of the humidity mode parameter). If the Psychrometrics routine is called with an absolute humidity ratio greater than the saturation humidity ratio for the specified temperature, the humidity ratio will be reset to the saturation humidity ratio and a warning will be printed to the simulation log and list files. The Psychrometrics routine returns the inlet air pressure, temperature, relative humidity, humidity ratio and enthalpy.

No Flow Condition

Since a heat pipe is a passive device, the only control over whether Type689 transfers energy from one stream to the other is the flow rate of the two air streams. If either air stream flow rate is set to zero or if the temperature of air stream 1 is less than or equal to the temperature of air stream 2 then energy cannot be transferred by the device. Under these circumstances, the outlet air enthalpy and humidity ratio of each air stream are set to their corresponding inlet values. The outlet pressures are set to the inlet pressures minus the user specified pressure drop across each end of the device. Equations 689.1a and 689.1b are used to calculate the outlet air pressures.

$$P_{out,1} = P_{in,1} - \Delta P_1 \qquad \text{(Eq. 689.1a)}$$

$$P_{out,2} = P_{in,2} - \Delta P_2 \quad \text{(Eq. 689.1b)}$$

To fully determine the air outlet states, the Psychrometrics routine is called with outlet pressure, humidity ratio, and enthalpy. The Psychrometrics routine returns outlet air relative humidity and temperature for each stream.

Flow Condition

If air is flowing across both ends of the heat pipe then the device can transfer heat. It first makes a call to the TRNSYS Air Properties routine to determine the specific heat of air at the two stream inlets as a function of the inlet air stream temperatures.

Type689 next determines the minimum capacitance air stream as it is this stream that will limit the amount of energy that may be transferred. The capacitance of each air stream is calculated using equation 689.2.

$$C_{\min} = MIN\left(\dot{m}_{air,1}\ Cp_{air,1}, \dot{m}_{air,2}\ Cp_{air,2}\right) \quad \text{(Eq. 689.2)}$$

The energy transferred is given by equation 689.3

$$\dot{Q}_{air} = \varepsilon\ C_{\min}\left(T_{air,in1} - T_{air,in2}\right) \quad \text{(Eq. 689.3)}$$

The enthalpy of air exiting each stream is then calculated using equations 689.4a and 689.4b

$$h_{out,1} = h_{in,1} - \frac{\dot{Q}_{air}}{\dot{m}_{air,1}} \quad \text{(Eq. 689.4a)}$$

$$h_{out,2} = h_{in,2} + \frac{\dot{Q}_{air}}{\dot{m}_{air,2}} \quad \text{(Eq. 689.4b)}$$

For the moment, it is assumed that the humidity ratio of exiting air is equal to the humidity ratio of entering air for each of the two streams. This assumption, if incorrect will be corrected by a call to the Psychrometrics routine. Psychrometrics is called with the outlet air enthalpy, the inlet air humidity ratio and the outlet air pressure. As with previous calls to Psychrometrics, if the humidity ratio sent to the routine is above the saturation point for the given value of enthalpy, the humidity ratio returned will be reset to the saturation condition and a warning will be printed to the simulation list and log files.