TYPE 670: AIR HEATING COIL (KEEPS THE OUTLET AIR TEMPERATURE BELOW A USER-SPECIFIED SETPOINT)

General Description

Type670 simulates an air heating coil with an internally controlled bypass damper that acts to maintain the outlet air temperature above the inlet air temperature and below a user-specified set point temperature.

Nomenclature

Cp_{air}	[kJ/kg.K]	Specific heat of the air stream
$\frac{dh}{dT}$		Change in air enthalpy with a change in air dry bulb temperature
$C_{\min}$	[kJ/hr.K]	Minimum capacitance
$C_{\min,req}$	[kJ/hr.K]	Minimum capacitance required to maintain the air outlet temperature
$\dot{m}_{liq}$	[kg/hr]	Mass flow rate of liquid
Cp_{liq}	[kJ/kg.K]	Specific heat of the liquid stream
$\dot{m}_{air}$	[kg/hr]	Total mass flow rate of air
$\dot{Q}_{\max}$	[kJ/hr]	Maximum amount of energy that can be transferred between the liquid and air streams.
$\dot{Q}_{hx}$	[kJ/hr]	Required amount of energy transferred between the liquid and air streams to maintain the air outlet temperature.
ε	[0..1]	Heat exchanger (air to coil) effectiveness.
$T_{liq,in}$	[ºC]	Temperature of liquid entering the coil.
$T_{liq,out}$	[ºC]	Temperature of liquid exiting the coil
$T_{air,in}$	[ºC]	Temperature of air entering the coil.
$h_{air,out}$	[kJ/kg]	Enthalpy of air exiting the device (after mixing air that passed over the coil and bypassed air)
$h_{air,in}$	[kJ/kg]	Enthalpy of air entering the coil.
$h_{air,out,req}$	[kJ/kg]	Required enthalpy of air exiting the device in order to maintain the user set point temperature.
$\dot{m}_{air,req}$	[kg/hr]	Mass flow rate of air across the coil required to maintain the user specified outlet air temperature.
$T_{out,coil}$	[ºC]	Temperature of air exiting the coil before remixing with bypass air.

Detailed Description

Type670 models an heating device in which air is passed across coils containing a hot liquid. The air exits hotter and at the same absolute humidity ratio as it entered the device. The user specifies the iar inlet and liquid inlet conditions. Type670 is also equipped with an internally controlled damper that modulates the fraction of air that is bypassed around the heating coil so that the outlet temperature of the air does not exceed a user specified maximum temperature. The damper also acts to insure that the outlet air temperature does not fall below the liquid inlet temperature. A schematic of the Type670 heating coil is shown in Figure 1.

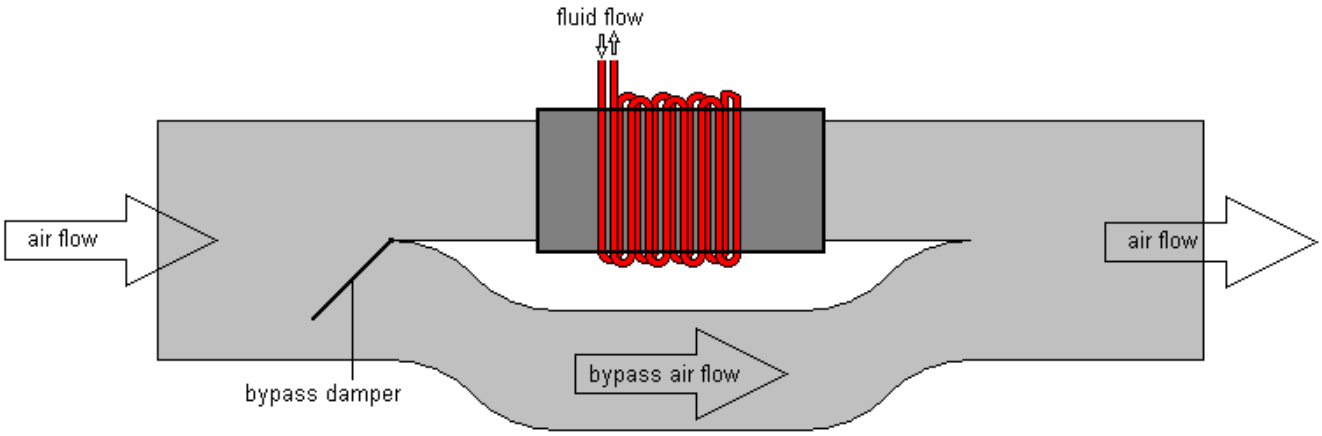


Figure 1: Air Heating Coil Schematic

Type670 first performs a call to the TRNSYS psychrometrics routine in order to obtain those air properties for the inlet air stream not specified by the user among the component's inputs. The user is required to specify inlet air pressure, dry bulb temperature and either absolute humidity ratio or relative humidity. If dry bulb temperature and humidity ratio are inputs to the model and a humidity ratio higher than the saturation humidity ratio for that dry bulb temperature is specified, the psychrometrics routine will reset the humidity ratio to its saturated condition and print a warning in the TRNSYS list file. In The psychrometrics routine returns the inlet air enthalpy and either relative humidity or humidity ratio, whichever was not supplied by the user.

If either the flow rate of liquid or the flow rate of air entering the heating coil is set to zero then Type670 assumes that there is no heat transferred to the air. The temperature of liquid exiting the device is set to the temperature of liquid entering the device and the outlet air state is determined by setting the outlet air enthalpy equal to the inlet air enthalpy, by setting the outlet air humidity ratio equal to the inlet air humidity ratio and by taking pressure drop effects into account in a second call to the Psychrometrics routine. Because of pressure drop effects, the outlet air state can differ slightly from the inlet air state. Presusre drop effects are accounted for in Type670 even if air is not flowing through the device.

Type670 next checks for a pair of special cases that also result in zero heat transfer between the air and liquid streams. If the inlet air temperature is greater than the outlet air set point temperature then all of the air will be bypassed around the coil and consequently, there will be no energy transfer between the air and liquid streams. If the inlet liquid temperature is less than the air inlet temperature then cooling of the air stream would result from passing the air across the coil. Again in this case, all the air is bypassed around the coil and no energy transfer takes place. If both of these special cases have been ruled out then at least some of the inlet air will be passed across the coil.

Type670 first assumes that all of the air will pass across the coil. It calculates the specific heat of the air stream using equation 670.1 in which dh is a slight change in enthalpy and dT is a slight change in temperature.

$$Cp_{air} = \frac{dh}{dT} \qquad \text{(Eq. 670.1)}$$

The derivative dh/dT is determined by first calling the Psychrometrics routine with the inlet air temperature, then by recalling the Psychrometrics routine with the inlet air temperature plus 1 degree C. The air enthalpy from each call is recorded. With the air specific heat known, it is then possible to determine whether the air or the water side of the air / coil system represents the minimum capcitance side. The minimum capacitance is determined using equation 670.2

$$C_{\min} = MIN\left(\dot{m}_{liq}\ Cp_{liq}, \dot{m}_{air}\ Cp_{air}\right) \quad \text{(Eq. 670.2)}$$

The maximum amount of energy that can be transferred between the air stream and the fluid stream is then

$$\dot{Q}_{\max} = \varepsilon\ C_{\min}\left(T_{liq,in} - T_{air,in}\right) \quad \text{(Eq. 670.3)}$$

Assuming that all of the air passes across the coil, the enthalpy of air exiting the coil is given by equation 670.4

$$h_{air,out} = h_{air,in} + \frac{\dot{Q}_{\max}}{\dot{m}_{air} Cp_{air}} \quad \text{(Eq. 670.4)}$$

The Psychrometrics routine is again called, this time with air pressure (including pressure drop effects), air humidity ratio and outlet air enthalpy to determine the temperature of the exiting air. At this point, Type670 has assumed that the entire air stream passes across the coil. If the returned temperature is below the user defined set point temperature, then the Type670 control criteria of maintaining the outlet air temperature above the liquid inlet temperature and below a user defined set point temperature has been satisfied and the liquid outlet temperature can be calculated using equation 670.5

$$T_{liq,out} = T_{liq,in} - \frac{\dot{Q}_{\max}}{\dot{m}_{liq}\ Cp_{liq}} \quad \text{(Eq. 670.5)}$$

If, however, the temperature returned by Psychrometrics is above the outlet air temperature, an appropriate bypass fraction must be calculated. Equations 670.1 through 670.4 are such that they can be used backwards to determine an appropriate air flow rate across the coil that will result in the desired outlet temperature. Such is not always the case and often, air side components that contain set points must be solved iteratively to find an appropriate bypass.

To back calculate the bypass fraction, Psychrometrics s again called, this time with air outlet pressure (known based on air inlet pressure and pressure drop), air outlet humidity ratio (equal to the air inlet humidity ratio) and the desired air outlet temperature. This time, Psychrometrics returns the corresponding outlet air enthalpy. With enthalpy known, the required heat transfer between the air and liquid streams can be calculated on a per unit mass flow basis using equation 670.6, which is simply a rearrangement of equation 670.4 assuming a unitary mass flow rate.

$$\dot{Q}_{hx} = Cp_{air}\left(h_{air,out,req} - h_{air,in}\right) \quad \text{(Eq. 670.6)}$$

The required minimum capacitance can next be calculated using equation 670.7, which is merely a rearrangement of equation 670.3

$$C_{\min,req} = \frac{\dot{Q}_{hx}}{\varepsilon\left(T_{liq,in} - T_{air,in}\right)} \qquad \text{(Eq. 670.7)}$$

Once the required minimum capacitance is known, the required mass flow rate can be calculated by rearranging equation 670.2

$$\dot{m}_{air,req} = \frac{C_{\min}}{Cp_{liq}} \qquad \text{(Eq. 670.8)}$$

Equation 670.8 provides the required air mass flow rate across the coil. The air flow through the bypass is the difference between the total air flow and the amount that must cross the coil in order to maintain the outlet temperature.

The temperature of the liquid exiting the coil is calculated in the same manner as it was when all the air flowed across the coil. Q_{max} is replaced by Q_{hx} in equation 670.5. The temperature of air exiting the coil (as opposed to the temperature of the air exiting the device) is guven by equation 670.9.

$$T_{out,coil} = T_{air,in} - \frac{\dot{Q}_{hx}}{\dot{m}_{air,coil} Cp_{liq}} \qquad \text{(Eq. 670.9)}$$