TYPE 752: SIMPLE COOLING COIL

General Description

Type752 models a cooling coil using a bypass fraction approach. A user-defined fraction of the inlet air stream is assumed to reach the average temperature of the liquid filled coils of the device while the remaining fraction is assumed to completely bypass the effects of the coil. The two air streams then mix back together and the outlet conditions are calculated. The Type752 cooling coil differs from other cooling coil models in that it does not treat the liquid side of the system at all. It is assumed that the coil is not constrained by the liquid side or in other words, that the liquid side can absorb as much energy from the air side as needed. Type752 can be used in three different control modes; in one control mode, the outlet dry bulb temperature of the air stream is maintained at a desired level. In another control mode the air outlet humidity (whether relative humidity or absolute humidity ratio) is maintained at a desired level. In the third control strategy both temperature and humidity are maintained at desired levels. This cooling coil model is not designed to be used in a free float mode because nothing is known about the conditions of liquid entering the device. The model reports the amount of energy removed from the air stream and (if both temperature and humidity are controlled) the amount of reheat energy required to bring the temperature back up to the desired level after meeting the humidity requirement.

Nomenclature

$\dot{m}_{cond}$	[kg/hr]	The mass flow rate of condensate draining from the cooling coil.
$\dot{m}_{air}$	[kg/hr]	The mass flow rate of air entering the cooling coil.
P_{out}	[atm]	The pressure of air exiting the cooling coil.
P_{in}	[atm]	The pressure of air entering the cooling coil.
ΔP	[atm]	The pressure drop of air as it passes through the cooling coil.
$h_{air,in}$	[kJ/kg]	The enthalpy of air entering the cooling coil.
$h_{air,out}$	[kJ/kg]	The enthalpy of air exiting the cooling coil (after remixing with bypass air)
$h_{air,coil}$	[kJ/kg]	The enthalpy of air leaving the coils before remixing.
$h_{air,desired}$	[kJ/kg]	The enthalpy of the desired outlet air state.
$\dot{Q}_{total}$	[kJ/hr]	The total cooling energy transferred from the air stream
$\dot{Q}_{reheat}$	[kJ/hr]	The reheat energy required to bring the outlet air temperature back to its desired level after dehumidifying the air to its desired level.
$\omega_{air,in}$	[kgH_2O/kgAir]	The humidity ratio of air entering the cooling coil.
$\omega_{air,out}$	[kgH_2O/kgAir]	The humidity ratio of air exiting the cooling coil (after remixing)
$\omega_{air,coil}$	[kgH_2O/kgAir]	The humidity ratio of air exiting the coils before remixing.
f_{bypass}	[-]	The fraction of inlet air that is bypassed around the coils.

Detailed Description

The bypass fraction approach to modeling cooling coils is quite common. In a cooling coil, an air stream passes over a series of coils that contain a liquid that is at a lower temperature than the air stream. The air stream cools and is dehumidified as it passes over the coils but does not necessarily exit the cooling coil at its saturated conditions and at the average coil temperature. The equations for predicting the heat

and mass transfer that occur as an air stream passes over a partially wetted series of coils is extremely complex; the bypass fraction approach is a simplified method of estimating coil performance. In the bypass fraction approach, it is assumed that the air flowing into the cooling coil is split into two streams. One stream passes over the coils and exits saturated at the average coil temperature. The other stream bypasses the coil completely. The cooled, saturated air stream and the unchanged stream are then remixed to form the air state that actually exits the coil. It is left to the user to determine an appropriate coil bypass fraction.

At each time step, Type752 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, temperature and either relative humidity or humidity ratio depending upon the value of PARAMETER 1. If the 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. The Psychrometrics routine also returns the density of dry air. Next, a call is made to the TRNSYS Air Properties routine to determine the temperature dependent specific heat of air at the inlet temperature condition.

The Type752 cooling coil can be operated in three distinct control modes; outlet air dry bulb temperature control, outlet air dry bulb temperature and outlet air humidity mode, and outlet air humidity mode. For humidity levels, the user either enters a desired outlet air relative humidity or a desired outlet air humidity ratio, depending again upon the value of PARAMETER 1. If relative humidity mode is chosen, Type752 next performs a call to the Psychrometrics routine with the desired air outlet conditions. Psychrometrics returns an absolute humidity mode so even if the user chooses to specify and control based on relative humidity, internal calculations are always done based on absolute humidity ratio.

No Flow Condition

If either air is not flowing through the cooling coil, if the air bypass fraction is greater than or equal to 1 or if the cooling coil is OFF (INPUT 8 = 0) Type752 sets the outlet air temperature to the inlet temperature, sets the outlet air pressure to the inlet air pressure minus the air side pressure drop (specified as an input to the model), sets the outlet air humidity ratio to the inlet air humidity ratio and the outlet air enthalpy to the inlet air enthalpy. The equation used to calculate air outlet pressure is:

$$P_{out} = P_{in} - \Delta P \qquad \text{(Eq. 752.1)}$$

The total cooling and reheat energies are set to zero. Before exiting, Type752 performs a last call to the Psychrometrics routine to fully determine the air outlet state. Because of the air side pressure drop, condensation of the air stream may occur in the device. As with the first call to the Psychrometrics routine, the humidity ratio may be reset if saturated conditions occur. If after the call to the Psychrometrics routine, the outlet humidity ratio is not equal to the inlet humidity ratio, the mass flow rate of condensate is calculated according to equation 752.2.

$$\dot{m}_{cond} = \dot{m}_{air}\left(\omega_{air,in} - \omega_{air,out}\right) \qquad \text{(Eq. 752.2)}$$

Flow Condition (Temperature Control)

If air is flowing through the cooling coil, the bypass fraction is less than 1, the cooling coil is ON and Type752 is in its temperature control mode, the outlet air state is set by assuming that the outlet air humidity ratio is equal to the inlet air humidity ratio, that the outlet air enthalpy is equal to the inlet air enthalpy, and that the outlet air pressure is given by equation 752.1. A call to the Psychrometrics routine is made to determine what the temperature of the outlet air would be under these assumed conditions. If the returned outlet air temperature is already below the desired outlet air temperature, there is nothing that the cooling coil should do to further condition the air. The total cooling and reheat energies are set to zero and the flow rate of any possible condensate is calculated using equation 752.2. If, on the other hand the returned temperature is higher than the desired temperature, then the cooling coil can act to reduce the temperature of the outlet air. The inlet air conditions are saved since they will be needed when the bypass air is remixed with the air that flows across the coil. Next, an iterative process begins to determine the coil temperature that, after the coil air is remixed with the bypass air, will result in the desired mixed air dry bulb temperature. The iterative process is fairly simple; an initial guess of the temperature and humidity ratio of the air exiting the coil (before remixing) is made. Type752 initially guesses that the temperature and humidity ratio of the air exiting the coil are equal to the inlet values. Type752 then makes a call to the Psychrometrics routine to fully determine the coil air state, then mixes this air with the bypassed air according to equations 752.3a and 752.3b.

$$h_{air,out} = f_{bypass}\ h_{air,in} + \left(1 - f_{bypass}\right) h_{air,coil} \qquad \text{(Eq. 752.3a)}$$

$$\omega_{air,out} = f_{bypass}\ \omega_{air,in} + \left(1 - f_{bypass}\right) \omega_{air,coil} \qquad \text{(Eq. 752.3b)}$$

Another call is made to the Psychrometrics routine, this time with the mixed air conditions and the outlet pressure defined by equation 752.1. The returned dry bulb temperature is compared with the desired outlet air dry bulb temperature. If the returned dry bulb temperature is higher than the desired temperature, a lower value of coil temperature is guessed. Conversely, if the returned dry bulb temperature is lower than the desired outlet air temperature, a higher value of coil temperature is guessed. Iteration continues until the difference between the desired outlet temperature and the returned outlet temperature are within a certain tolerance or until 100 iterations have passed. The convergence tolerance is set in the Fortran code of Type752 and can be modified by changing the value of T_CONV, recompiling the code and relinking the appropriate DLL.

Once an appropriate coil temperature has been found, the total cooling energy is calculated using equation 752.4

$$\dot{Q}_{total} = \dot{m}_{air}\left(h_{air,in} - h_{air,out}\right) \qquad \text{(Eq. 752.4)}$$

The reheat energy is set to zero and the mass flow rate of condensate is determined using equation 752.2.

Flow Condition (Temperature and Humidity Control)

Temperature and humidity control is only slightly different than temperature only control. Recall that whether the user has chosen to enter humidity values as absolute humidity ratios or relative humidities, internally Type752 uses absolute humidity ratio in its calculations and as set point values. The outlet air state is again set by assuming that the outlet air humidity ratio is equal to the inlet air humidity ratio, that

the outlet air enthalpy is equal to the inlet air enthalpy, and that the outlet air pressure is given by equation 752.1. A call to the Psychrometrics routine is made to determine what the temperature of the outlet air would be under these assumed conditions. If the returned outlet air temperature is already below the desired outlet air temperature, there is nothing that the cooling coil should do to further condition the air. The total cooling and reheat energies are set to zero and the flow rate of any possible condensate is calculated using equation 752.2. If, on the other hand the returned temperature is higher than the desired temperature, then the cooling coil can act to reduce the temperature of the outlet air and to reduce the absolute humidity ratio of the outlet air. The inlet air conditions are saved since they will be needed when the bypass air is remixed with the air that flows across the coil. Next, a two level iterative process begins to determine the coil temperature that, after the coil air is remixed with the bypass air, will result in the desired mixed air dry bulb temperature and humidity ratio. Because these coil temperatures may well be different, the lower of the two is determined and is used as the coil temperature in the calculation of the total cooling energy. The air is then reheated if the desired dry bulb temperature is higher than the coil temperature required to meet the desired humidity ratio condition. The iterative processes are fairly simple and the iteration to find an appropriate coil temperature to meet the desired humidity ratio is nested inside the iteration to find an appropriate coil temperature to meet the desired outlet dry bulb temperature.

In the outlet air temperature iteration, an initial guess of the temperature and humidity ratio of the air exiting the coil (before remixing) is made. Type752 initially guesses that the temperature and humidity ratio of the air exiting the coil are equal to the respective inlet values. Type752 then makes a call to the Psychrometrics routine to fully determine the coil air state, then mixes this coil air with the bypassed air using equations 752.3a and 752.3b.

With the mixed air state values in hand, another call is made to the Psychrometrics routine. The returned dry bulb temperature is compared with the desired outlet air dry bulb temperature. If the returned dry bulb temperature is higher than the desired temperature, a lower value of coil temperature is guessed. Conversely, if the returned dry bulb temperature is lower than the desired outlet air temperature, a higher value of coil temperature is guessed. Iteration continues until the difference between the desired outlet temperature and the returned outlet temperature are within a certain tolerance or until 100 iterations have passed. The convergence tolerance is set in the Fortran code of Type752 and can be modified by changing the value of T_CONV, recompiling the code and relinking the appropriate DLL.

Once Type752 has converged upon a coil temperature that satisfies the desired outlet temperature condition, it next checks the mixed air humidity ratio against the desired outlet air humidity ratio. If the humidity ratio is lower than desired, the coil should not further condition the air and it exits the iteration process. Thus it is possible that given certain inlet air conditions, the coil would be able to meet a desired outlet air temperature but not the desired air outlet humidity ratio when in control mode 2 or 3. If the mixed (outlet) air humidity ratio is higher than the desired value, then the coil must further cool the air in order to dehumidify it. Using the same iterative scheme, the coil temperature is further reduced until the humidity ratio of coil air returned from the Psychrometrics routine, when mixed with bypass air according to equation 752.3b results in an outlet air humidity ratio equal to the desired level.

Once the coil temperature has been found, the total cooling energy is calculated using equation 752.4. Because the air may now be exiting the device at a lower temperature than is desired by the user, reheat may be used to return the air to the desired level. The reheat energy is calculated using equation 75.2.5

$$\dot{Q}_{reheat} = \dot{m}_{air}\left(h_{air,desired} - h_{air,out}\right) \qquad \text{(Eq. 752.5)}$$

In which $h_{air,desired}$ is found through a call to Psychrometrics using the mixed air humidity ratio calculated in equation 752.3b and the desired outlet air temperature and $h_{air,out}$ is the value calculated using equation 752.3a.

Flow Condition (Humidity Control)

If air is flowing through the cooling coil, the bypass fraction is less than 1, the cooling coil is ON and Type752 is in its humidity control mode, the outlet air state is set by assuming that the outlet air humidity ratio is equal to the inlet air humidity ratio, that the outlet air enthalpy is equal to the inlet air enthalpy, and that the outlet air pressure is given by equation 752.1. A call to the Psychrometrics routine is made to determine what the temperature of the outlet air would be under these assumed conditions. If the returned outlet air humidity ratio is already below the desired outlet air humidity ratio, there is nothing that the cooling coil should do to further dehumidify the air. The total cooling and reheat energies are set to zero and the flow rate of any possible condensate is calculated using equation 752.2. If, on the other hand the returned humidity ratio is higher than the desired humidity ratio, then the cooling coil can act to dehumidify the outlet air. The inlet air conditions are saved since they will be needed when the bypass air is remixed with the air that flows across the coil. Next, an iterative process begins to determine the coil temperature that, after the coil air is remixed with the bypass air, will result in the desired mixed air absolute humidity ratio. The iterative process is fairly simple; an initial guess of the temperature and humidity ratio of the air exiting the coil (before remixing) is made. Type752 initially guesses that the temperature and humidity ratio of the air exiting the coil are equal to the inlet values. Type752 then makes a call to the Psychrometrics routine to fully determine the coil air state, then mixes this air with the bypassed air according to equations 752.3a and 752.3b.

Another call is made to the Psychrometrics routine, this time with the mixed air conditions and the outlet pressure defined by equation 752.1. The returned humidity ratio is compared with the desired outlet air humidity ratio. If the returned value is higher than the desired value, a lower value of coil temperature is guessed. Conversely, if the returned value of humidity ratio is lower than the desired value, a higher value of coil temperature is guessed. Iteration continues until the difference between the desired outlet humidity ratio and the returned humidity ratio are within a certain tolerance or until 100 iterations have passed. The convergence tolerance is set in the Fortran code of Type752 and can be modified by changing the value of W_CONV, recompiling the code and relinking the appropriate DLL.

Once an appropriate coil temperature has been found, the total cooling energy is calculated using equation 752.4, the reheat energy is set to zero and the mass flow rate of condensate is determined using equation 752.2.