TYPE 508: COOLING COIL WITH VARIOUS CONTROL MODES

General Description

Type508 models a cooling coil using one of four control modes. The cooling coil is modeled using a bypass approach in which the user specifies a fraction of the air stream that bypasses the coil. The remainder of the air stream is assumed to exit the coil at the average temperature of the fluid in the coil and at saturated conditions. The two air streams are remixed after the coil. In its unrestrained (uncontrolled) mode of operation, the coil cools and dehumidifies the air stream as much as possible given the inlet conditions of both the air and the fluid streams. The model is alternatively able to internally bypass fluid around the coil so as to maintain the outlet air dry bulb temperature above a user specified minimum, to maintain the air outlet absolute humidity ratio above a user specified minimum or to maintain the fluid outlet temperature below some user specified maximum.

Nomenclature

$\dot{m}_{cond}$	[kg/hr]	Flow rate of condensate draining from the coil.
$\dot{m}_{fluid}$	[kg/hr]	Total flow rate of fluid through the coil (includes bypassed fluid).
$\dot{m}_{air}$	[kg/hr]	Total flow rate of air through the coil (includes bypassed air).
f_{bypass}	[0..1]	Fraction of air bypassed around the coil.
$\omega_{air,out}$	[kgH_2O/kgAir]	Absolute humidity ratio of air exiting the coil before mixing
$\omega_{air,in}$	[kgH_2O/kgAir]	Absolute humidity ratio of air entering the coil.
$\omega_{air,mix}$	[kgH_2O/kgAir]	Absolute humidity ratio of air exiting the coil remixed with bypassed air.
$h_{air,out}$	[kJ/kg]	Enthalpy of air exiting the coil before mixing
$h_{air,in}$	[kJ/kg]	Enthalpy of air entering the coil.
$h_{air,mix}$	[kJ/kg]	Enthalpy of air exiting the coil remixed with bypassed air.
h_{cond}	[kJ/kg]	Enthalpy of condensate draining from the coil
$\dot{Q}_{fluid}$	[kJ/hr]	Energy transferred from the air stream to the fluid stream.
Cp_{fluid}	[kJ/kg.K]	Specific heat of coil fluid
$T_{fluid,out}$	[ºC]	Temperature of fluid exiting the coil (before remixing with bypassed fluid)
$T_{fluid,in}$	[ºC]	Temperature of fluid entering the coil.

Detailed Description

A cooling coil is a device that dehumidifies and cools air by passing it in proximity to tubes containing a cold liquid. Energy is transferred from the hotter air to the colder liquid. Moisture is transferred as water condenses from the air stream and flows out of the coil. Because the surfaces of the coil tubes are wet with condensation, the heat transfer between the air and the coil is not easy to determine. A common method for modeling a cooling coil is to split the air stream that passes across the coil into two parts. One part of the air stream passes across the coils themselves and exits in a saturated condition at the temperature of the fluid flowing through the coils. The other portion of the air stream (called the bypass fraction) does not come into any contact with the coil but is bypassed around the coil at its inlet state

where it is remixed with the fraction of the air stream that did pass through the coil. Figure 1 shows a schematic diagram of the technique used to model cooling coils.

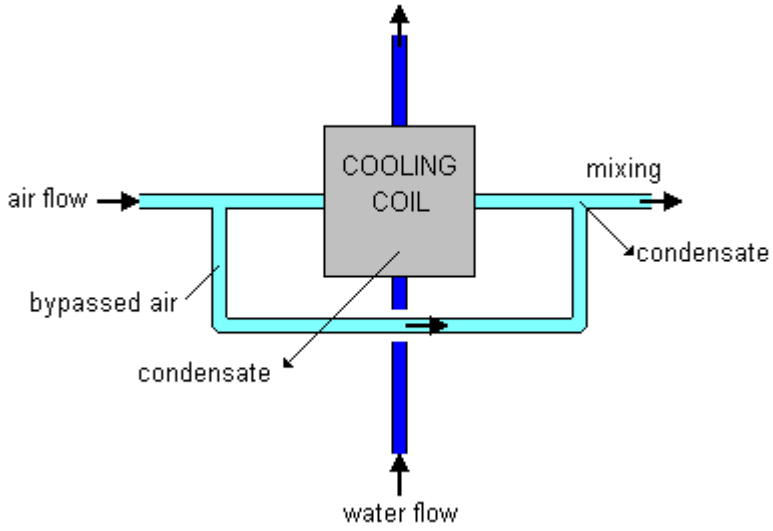


Figure 1: Cooling Coil Model Schematic

As can be seen in Figure 1, two opportunities for condensation arise. The first is the condensation that occurs on the coils themselves. The second occurs when the cooled, dehumidified air remixes with the inlet air. In its simplest mode of operation, Type508 operates exactly as shown in Figure 1; a user specified amount of air enters the device. A user specified fraction of the air passes through the coil where it comes to saturation at the average of the entering and exiting water temperature. The remainder of the air bypasses the coil and is then remixed with the cooled dehumidified saturated air. The only complication in the scheme is that in order to find the average water temperature in the coil, it is necessary to guess an outlet temperature and iterate until the energy transferred from the air stream matches the energy transferred into the water stream. The amount of condensate that flows from the coil itself is given by equation 508.1

$$\dot{m}_{cond} = \dot{m}_{air}\left(1 - f_{bypass}\right)\left(\omega_{air,out} - \omega_{air,in}\right) \qquad \text{Eq. 508.1}$$

The condensate and the air stream both exit the coil at the same temperature. Through a call to the TRNSYS Steam Properties routine, the enthalpy of the condensate is found. The energy transferred from the air stream to the fluid stream is then given by equation 508.2

$$\dot{Q}_{fluid} = \dot{m}_{air}\left(1 - f_{bypass}\right)\left(h_{air,in} - h_{air,out}\right) - \dot{m}_{cond}\ h_{cond} \qquad \text{Eq. 508.2}$$

A new outlet fluid temperature can then be calculated using equation 508.3.

$$T_{fluid,out} = T_{fluid,in} + \frac{\dot{Q}_{fluid}}{\dot{m}_{fluid} Cp_{fluid}} \qquad \text{Eq. 508.3}$$

Once a converged solution for outlet fluid temperature has been found that balances the energy transferred from the air with the energy transferred to the fluid, the air stream that passed through the coil is mixed with the air stream that bypassed the coil using equations 508.4a and 508.4b.

$$h_{air,mix} = (1 - f_{bypass})\, h_{air,out} + f_{bypass}\; h_{air,in} \qquad \text{Eq. 508.4a}$$

$$\omega_{air,mix} = (1 - f_{bypass})\, \omega_{air,out} + f_{bypass}\; \omega_{air,in} \qquad \text{Eq. 508.4b}$$

With these two values as well as the outlet air pressure (inlet air pressure minus the user specified pressure drop across the coil), the TRNSYS Psychrometrics routine is called to determine the remainder of the mixed air properties. As with all calls to Psychrometrics, if conditions resulting in saturated air are passed to the routine, it warns the user and resets one or the other of the two passed properties depending upon the mode. In this case, if over saturated conditions are passed, the humidity ratio is reset to the saturation condition for the specified enthalpy. The remaining moisture content is assumed to flow out as condensate. The two condensate streams are mixed before being reported as an output of this component.

The above discussion leads to outlet fluid and air conditions for an unrestrained cooling coil. In such a device, there is no control on either the outlet fluid or on the outlet air; the cooling coil does whatever it can to condition the air stream based upon entering air and water conditions. Type508, however, is equipped with a number of available control modes which allow the user to maintain the outlet air temperature above a user specified minimum, maintain the outlet air humidity ratio above a user specified minimum or maintain the outlet fluid temperature below a user specified maximum. In all three control mode cases, the Figure 1 cooling coil is modified to allow not only the air flow to be bypassed around the coil but the water flow as well. Figure 2 shows a cooling coil model in which both the air and the water streams can be bypassed around the coil. In Type508, the bypass fraction of the air stream is specified by the user while the bypass fraction of the water side is adjusted internally to meet the required air or water outlet condition.

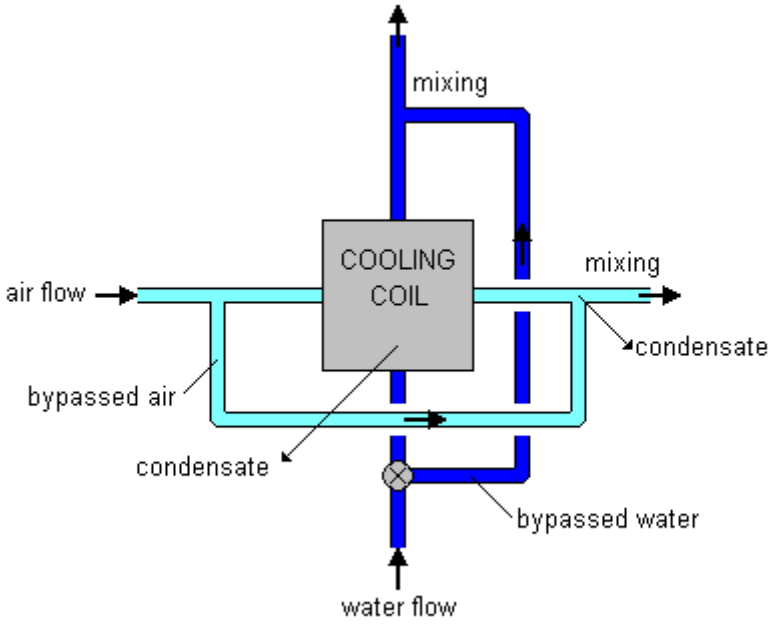


Figure 2: Controlled (Restrained) Cooling Coil Model Schematic