TYPE 697: PERFORMANCE MAP COOLING COIL

General Description

Type697 models a simple air cooling device that removes energy from an air stream according to performance data found in a combination of three external data files and based upon the flow rates and inlet conditions of the air stream and a liquid stream. Normally a water stream is used but if the external data is available for other liquids, that data can be used equally well.

Nomenclature

$\dot{m}_{cond}$	[kg/hr]	The mass flow rate of condensate draining from the cooling coil.
$\dot{m}_{liquid}$	[kg/hr]	The mass flow rate of liquid flowing through 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.
$T_{air,in}$	[ºC]	The temperature of air entering the cooling coil.
$T_{air,out}$	[ºC]	The temperature of air exiting the cooling coil.
$\dot{Q}_{sens}$	[kJ/hr]	The sensible cooling energy transferred from the air stream.
$\dot{Q}_{total}$	[kJ/hr]	The total cooling energy transferred from the air stream
$\dot{Q}_{sens,rated}$	[kJ/hr]	The sensible cooling energy transferred from the air stream under rated conditions
$\dot{Q}_{total,rated}$	[kJ/hr]	The total cooling energy transferred from the air stream under rated conditions
R_{tc1} R_{tc2} R_{tc3}	[-]	The total cooling ratio corrections from the three data files.
R_{sc1} R_{sc2} R_{sc3}	[-]	The sensible cooling ratio corrections from the three data files.
$\omega_{air,in}$	[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.
$f_{vol,air}$	[-]	The dimensionless flow of air through the cooling coil.
$\dot{v}_{air}$	[l/s]	The volumetric flow rate of air flowing through the cooling coil.
$\dot{v}_{air,rated}$	[l/s]	The volumetric flow rate of air flowing through the cooling coil under rated conditions.
$f_{vol,liquid}$	[l/s]	The dimensionless flow of liquid through the cooling coil.
$\dot{v}_{liquid}$	[l/s]	The volumetric flow rate of liquid flowing through the cooling coil.
$\dot{v}_{liquid,rated}$	[l/s]	The volumetric flow rate of liquid flowing through the cooling coil under rated conditions.
Cp_{liquid}	[kJ/kg.K]	The specific heat of the liquid flowing through the cooling coil
Cp_{air}	[kJ/kg.K]	The specific heat of the air flowing through the cooling coil

Detailed Description

At each time step, Type697 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.

No Flow Condition

If either air or liquid is not flowing through the cooling coil Type697 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:

$$P_{out} = P_{in} - \Delta P \qquad \text{(Eq. 697.1)}$$

The sensible and total cooling energies are set to zero. Before exiting, Type697 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 even if the water side is not flowing. 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 697.2.

$$\dot{m}_{cond} = \dot{m}_{air}\left(\omega_{air,in} - \omega_{air,out}\right) \qquad \text{(Eq. 697.2)}$$

Flow Condition

If air and liquid are flowing through the cooling coil Type697 first calculates dimensionless volumetric flow fractions for both the air and water sides according to equation 697.3a and 697.3b.

$$f_{vol,air} = \frac{\dot{v}_{air}}{\dot{v}_{air,rated}} \qquad \text{(Eq. 697.3a)}$$

$$f_{vol,liquid} = \frac{\dot{v}_{liquid}}{\dot{v}_{liquid,rated}} \qquad \text{(Eq. 697.3b)}$$

Of course the volumetric flow rates of air and liquid at the current time are based on the user specified mass flow rates the user specified liquid density and the air density returned by the first call to the Psychrometrics routine.

Required Data

The performance of the cooling coil is based entirely on three data files, each of which is read through queries to the TRNSYS Data Reading subroutine. As such, the data files must conform in their syntax to a predefined format. In the case of Type697, three data files are required. The first provides basic performance data. The second provides correction factors to the performance based on varying air temperatures while the third provides correction factors to the performance data based on varying air flow rates. In the case of the basic performance data file, two independent variables are required. The first line of the data file must contain at least one value of dimensionless liquid volumetric flow rate. These values are obtained by dividing a given liquid flow rate by the liquid flow rate at rated conditions. The second line of the data file must contain at least one value of the inlet liquid temperature. The subsequent lines of the file must each contain two values, separated by at least one space. The first value is the ratio of the total (sensible and latent) cooling that can be accomplished at the given inlet conditions to the total cooling that can be accomplished at rated inlet conditions. The second value is the ratio of sensible cooling that can be accomplished at the current inlet conditions to the sensible cooling that can be accomplished at rated inlet conditions. One line of data (dependent values) must be provided for each possible pair of independent values. Thus if five values of dimensionless liquid flow rate and four values of entering liquid temperature are provided, twenty lines of dependent data values must be provided.

The second data file follows much the same format. In this case, the two independent variables are the wet and dry bulb temperatures of air entering the device. The first line of the data file must contain at least one value of the entering air dry bulb temperature (specified in ºC) and the second line must contain at least one value of the entering air wet bulb temperature. The same two dependent data values are provided; total cooling ratio and sensible cooling ratio.

The third data file differs only in that instead of two independent variables, one independent variable is provided. The first line of the data file must contain at least one value of dimensionless air flow rate. The value is calculated by dividing the volumetric air flow rate at current conditions by the volumetric air flow rate at rated conditions. In the third file, total cooling ratio and sensible cooling ratio are again provided as dependent values but in this case, only as many lines of data as there are values of dimensionless air flow rate are required. Sample data files are provided in the \trnsys16\TESS Models\SampleCatalodData\CoolingCoil\ directory. The same three files are reproduced at the end of this document for reference.

The TRNSYS Data Reading subroutine, while able to interpolate the dependent variable values in multiple dimensions, is unable to extrapolate beyond the data range given in the data files. If a value of one of the independent variables sent to the Data Reading routine is above or below the range present in the file, the Data Reading routine will print a warning to the TRNSYS simulation log and list files and will return the corresponding maximum or minimum value.

Device Performance

Once the current input data has been sent to the Data Reading routine and the three values of total cooling ratio and sensible cooling ratio have been returned, Type697 calculates the cooling coil performance based on equations 679.4a and 697.4b.

$$\dot{Q}_{total} = \dot{Q}_{total,rated}\ R_{tc1}\ R_{tc2}\ R_{tc3} \qquad \text{(Eq. 697.4a)}$$

$$\dot{Q}_{sens} = \dot{Q}_{sens,rated}\ R_{sc1}\ R_{sc2}\ R_{sc3} \qquad \text{(Eq. 697.4b)}$$

In which R_{tcx} denotes the total cooling ratio returned by one of the three data files and R_{scx} denotes the sensible cooling ratio returned by one of the three data files.

The temperature of air exiting the cooling coil is then determined using equation 697.5

$$T_{air,out} = T_{air,in} - \frac{\dot{Q}_{sens}}{\dot{m}_{air} Cp_{air}} \quad \text{(Eq. 697.5)}$$

The enthalpy of air exiting the cooling coil is given by 697.6.

$$h_{air,out} = h_{air,in} + \frac{\dot{Q}_{total}}{\dot{m}_{air}} \quad \text{(Eq. 697.6)}$$

The remainder of the exiting air properties are determined through a final call to the Psychrometrics routine. If the returned absolute humidity ratio is greater than the absolute humidity ratio of air entering the device, the air is assumed to have saturated. The outlet humidity is set to the inlet value and Psychrometrics is recalled. In this case, condensate has formed. The condensate is assumed to exit the device at the same temperature as air. The flow rate of condensate is given by equation 697.2. Because the calls to Psychrometrics can reset air conditions to their saturated values, the total and sensible cooling achieved by the device is recalculated based on equations 697.7 and 697.8.

$$\dot{Q}_{total} = \dot{m}_{air}\left(h_{air,in} - h_{air,out}\right) \quad \text{(Eq. 697.7)}$$

$$\dot{Q}_{sens} = \dot{m}_{air}\ Cp_{air}\left(T_{air,in} - T_{air,out}\right) \quad \text{(Eq. 697.8)}$$

The energy transferred to the liquid stream is equal to Q_{total} and the corresponding temperature rise in the liquid stream is given by equation 697.9

$$T_{liquid,out} = T_{liquid,out} + \frac{\dot{Q}_{total}}{\dot{m}_{liquid} Cp_{liquid}} \quad \text{(Eq. 697.9)}$$

Samples of the three data files appear here below.

Sample Entering Liquid Flow Correction Data File

```
0.7500   1.0000   1.2500            !Ratio of liquid flow rate to rated liquid flow rate
 7.2222   10.0000   12.7778          !Entering liquid temperature (C)
 1.1661   1.0914                    !Total cooling ratio, sensible cooling ratio
 1.0000   1.0000
 0.8420   0.8711
 1.1661   1.0914
 1.0000   1.0000
 0.8420   0.8711
 1.1661   1.0914
 1.0000   1.0000
 0.8420   0.8711
```

Sample Entering Air Temperature Correction Data File

```
21.1111 23.8889 26.6667 27.0000 29.4444 32.2222 35.0000   !Air dry-bulb temperature (C)
15.5556 18.3333 19.0000 19.4444 21.1111 23.8889           !Air wet-bulb temperature (C)
```

```
 0.84844         0.88163                              !Total cooling ratio, sensible cooling ratio
 0.97073         0.63339
 0.99615         0.57381
 1.00000         0.53409
 1.03038         0.53409
 1.06502         0.53409
 0.84844         1.04443
 0.97073         0.86117
 0.99615         0.81719
 1.00000         0.78787
 1.03038         0.67792
 1.06502         0.67792
 0.84844         1.16925
 0.97073         1.06990
 0.99615         1.03003
 1.00000         1.00000
 1.03038         0.86285
 1.06502         0.54811
 0.84844         1.20294
 0.97073         1.08303
 0.99615         1.06541
 1.00000         1.01728
 1.03038         0.89957
 1.06502         0.65256
 0.84844         10.00000
 0.97073         1.27234
 0.99615         1.22783
 1.00000         1.19777
 1.03038         1.08230
 1.06502         0.88025
 0.84844         10.00000
 0.97073         10.00000
 0.99615         10.00000
 1.00000         1.31408
 1.03038         1.20988
 1.06502         1.03622
 0.84844         10.00000
 0.97073         10.00000
 0.99615         10.00000
 1.00000         1.35968
 1.03038         1.30023
 1.06502         1.20115
```

Sample Entering Air Flow Correction Data File

```
0.750 0.813 0.875 0.938 1.000 1.063 1.125    !Ratio of air flow rate to rated air flow rate
 0.9620         0.8734                       !Total cooling ratio, sensible cooling ratio
 0.9735         0.9055
 0.9850         0.9376
 0.9925         0.9688
 1.0000         1.0000
 1.0070         1.0338
 1.0140         1.0675
```