TYPE 760: AIR TO AIR SENSIBLE HEAT EXCHANGER

General Description

Type760 uses an effectiveness – minimum capacitance approach to model an air to air heat exchanger that transfers only sensible energy. If moisture transfer as well as sensible energy transfer between the exhaust and fresh air streams is important, Type667 (an air to air heat recovery device) uses similar principals to this model but also accounts for moisture transfer between the air streams. Type760 includes five different control modes. In the first of these control modes, the outlet temperatures of the two air streams are completely uncontrolled. In the other four operation modes, the temperature of either the fresh or exhaust air streams is maintained either above or below a user defined set point.

Nomenclature

$\dot{m}_{fresh,in}$	[kg/hr]	Mass flow rate of air entering the "fresh air" side of the device.
$\dot{m}_{exh,in}$	[kg/hr]	Mass flow rate of air entering the "exhaust air" side of the device.
$T_{fresh,in}$	[C]	Temperature of air entering the "fresh air" side of the device.
$T_{exh,in}$	[C]	Temperature of air entering the "exhaust air" side of the device.
$\omega_{fresh,in}$	[kgH_2O/kgAir]	Absolute humidity ratio of air entering the "fresh air" side of the device.
$\omega_{exh,in}$	[kgH_2O/kgAir]	Absolute humidity ratio of air entering the "exhaust air" side of the device.
$\omega_{fresh,out}$	[kgH_2O/kgAir]	Absolute humidity ratio of air exiting the "fresh air" side of the device.
$\omega_{exh,out}$	[kgH_2O/kgAir]	Absolute humidity ratio of air exiting the "exhaust air" side of the device.
$h_{fresh,in}$	[kJ/kg]	Enthalpy of air entering the "fresh air" side of the device.
$h_{exhaust,in}$	[kJ/kg]	Enthalpy of air entering the "exhaust air" side of the device.
$h_{fresh,out}$	[kJ/kg]	Enthalpy of air exiting the "fresh air" side of the device.
$h_{exhaust,out}$	[kJ/kg]	Enthalpy of air exiting the "exhaust air" side of the device.
$C_{\min}$	[kJ/hr.K]	Minimum capacitance (mass flow rate times specific heat) air stream
Cp_{exh}	[kJ/kg.K]	Specific heat of air in the exhaust stream
Cp_{fresh}	[kJ/kg.K]	Specific heat of air in the fresh air stream.
$\dot{Q}_{sens}$	[kJ/hr]	Sensible energy transferred between air streams
ε	[0..1]	Sensible effectiveness of the device
$\dot{m}_{CondExh}$	[kg/hr]	The mass flow rate of condensate draining from the exhaust air stream
$\dot{m}_{CondExh}$	[kg/hr]	The mass flow rate of condensate draining from the fresh air stream

Detailed Description

In the Type760 air to air sensible heat exchanger, two streams of air are passed near each other in such a way as to allow for energy transfer but not for mass transfer of moisture to occur. Type760 models a heat exchanger using an "constant effectiveness – minimum capacitance" method and in so doing can be used to model a cross flow, counter flow or parallel flow device. The configuration of the air streams is built into the values of sensible effectiveness that must be supplied by the user. A schematic diagram of

a counter flow heat exchanger is shown in Figure 1. A counter flow configuration has been chosen merely for the sake of diagram clarity.

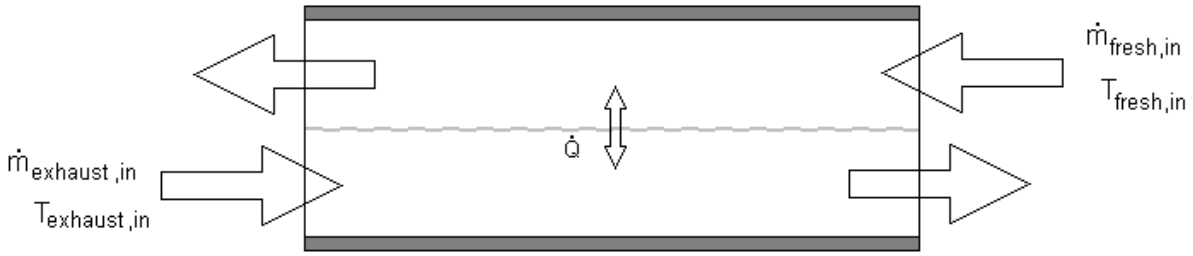


Figure 1: Air to Air Sensible Heat Exchanger Schematic

For the purposes of this description, the two are streams will be called the "fresh air" stream and the "exhaust air" stream because such heat exchangers can be used to precondition outside (fresh) air that is to be further conditioned by mechanical equipment before being delivered to a building thermal zone. An amount of air equal to the outside air is rejected or exhausted from the zone and the two air streams are often separated by a membrane that allows energy to transfer from one stream to the other. If the membrane is permeable to moisture, the device is often referred to as an air to air heat recovery device.

At each time step, Type760 performs a call to the TRNSYS Psychrometrics routine in order to obtain those air properties for the inlet exhaust and fresh air streams 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 for both the fresh air and exhaust air streams. 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.

No Flow Condition

If the Type760 heat exchanger is determined to be unable to transfer energy from one stream to the other either because the device control signal has been set to zero, or because one of the two air stream flow rates is set to zero, the outputs can readily be set. The outlet humidity ratios and enthalpies of each air stream are set to their corresponding inlet values. The outlet pressure of each stream is set to the appropriate inlet pressure minus the corresponding pressure drop as shown in equation 760.1

$$P_{out,exh} = P_{in,exh} - \Delta P_{exh} \qquad \text{(Eq. 760.1a)}$$

$$P_{out,fresh} = P_{in,fresh} - \Delta P_{fresh} \qquad \text{(Eq. 760.1b)}$$

The power drawn by the device is set to the user supplied rated power multiplied by the control signal. If the no flow condition has been met because one or the other air streams has a zero mass flow rate but the device control signal is set to 1, then Type760 will report that the heat exchanger is drawing its rated amount of power.

Flow Conditions

If Type760 is able to transfer energy between the air streams, it first performs a call to the TRNSYS Air Properties routine, which returns a temperature dependent value of the specific heat of air for each of the two air streams. The minimum capacitance air stream is determined using equation 760.2

$$C_{\min} = MIN\left(\dot{m}_{exh}\ Cp_{exh}, \dot{m}_{fresh}\ Cp_{fresh}\right) \quad \text{(Eq. 760.2)}$$

The maximum possible sensible energy transfer between the two streams is then

$$\dot{Q}_{sens} = \varepsilon_{sens}\ C_{\min}\left(T_{exh,in} - T_{fresh,in}\right) \quad \text{(Eq. 760.3)}$$

With the maximum sensible energy transfer known, the enthalpies of the air stream outlets can be determined using equations 760.4a and 760.4b.

$$h_{exh,out} = h_{exh,in} - \frac{\dot{Q}_{sens}}{\dot{m}_{exh}} \quad \text{(Eq. 760.4a)}$$

$$h_{fresh,out} = h_{fresh,in} + \frac{\dot{Q}_{sens}}{\dot{m}_{fresh}} \quad \text{(Eq. 760.4b)}$$

Because Type760 only transfers sensible energy, the outlet humidity ratios of each air stream are assumed to remain unchanged between their inlets and outlets. If this assumption turns out to be incorrect because condensation would occur in one air stream or the other, the humidity ratio of exiting air will be reset by the TRNSYS Psychrometrics routine to its saturated value.

The air stream outlet pressures (including pressure drop effects from the user supplied values), outlet enthalpies, and outlet humidity ratios are used in a call to the Psychrometrics routine to determine the remaining values of the air outlet state (temperature, and relative humidity) and to determine whether either of the two air streams has saturated. If they have, then altered values of humidity ratio will be returned by Psychrometrics. If condensation has occurred in either stream, the flow rates of that condensate are determined using equation 760.5a and 760.5b.

$$\dot{m}_{CondExh} = \dot{m}_{exh}\left(\omega_{exh,in} - \omega_{exh,out}\right) \quad \text{(Eq. 760.5a)}$$

$$\dot{m}_{CondFresh} = \dot{m}_{fresh}\left(\omega_{fresh,in} - \omega_{fresh,out}\right) \quad \text{(Eq. 760.5b)}$$

Condensate flowing from the exhaust air stream is assumed to drain out at the same temperature as air exiting from that stream. Likewise, condensate draining from the fresh air stream does so at the temperature of air exiting that stream.

The power drawn by the air to air sensible heat exchanger is simply set to the user defined rated power whenever the device is operating.

Controlled Operation

If Type760 is in control mode 0, then the user specified heat exchanger effectiveness is used to determine the maximum possible amount of energy that can be transferred between the two air streams given their inlet conditions using equation 760.3. Type760, however, is also outfitted with four other control modes whereby the outlet temperature of either the fresh air or the exhaust air stream will be maintained either above or below a user specified set point. The control modes are:

Control mode 1: Keep the fresh air outlet temperature below the user-specified temperature.
Control mode 2: Keep the fresh air outlet temperature above the user-specified temperature.
Control mode 3: Keep the exhaust air outlet temperature below the user-specified temperature.
Control mode 4: Keep the exhaust air outlet temperature above the user-specified temperature.

If one of the above control modes is active, Type760 first determines the outlet conditions of the two air streams using the user specified effectiveness. If the desired outlet condition is achievable (in other words if the amount of energy transfer required to achieve the desired outlet condition is less than the maximum energy transfer given the effectiveness) then Type760 calculates the appropriate effectiveness required to achieve the desired outlet temperature. If the desired outlet temperature is not achievable (more than the maximum possible energy transfer is required) then Type760 gets as close to the desired outlet condition as it can.

To draw a physical parallel with this theoretical approach, Type760 can be used to model a heat wheel. When turning at its rated speed, a heat wheel is able to transfer a certain amount of sensible energy. Its speed and its geometry combine to give the wheel a rated effectiveness. In the uncontrolled mode of operation, the heat wheel always rotates at its rated speed and transfers the maximum possible amount of energy. In controlled operation, the speed of the wheel is modified (and thus the effectiveness of the heat exchanger is modified) to achieve the desired outlet condition. If the desired outlet condition cannot be achieved, then the wheel simply turns at its maximum (rated) speed and transfers as much energy as possible.