TYPE 667: AIR TO AIR HEAT RECOVERY DEVICE

General Description

Type667 uses a "constant effectiveness – minimum capacitance" approach to model an air to air heat recovery device in which two air streams are passed near each other so that both energy and possibly moisture may be transferred between the streams. Because of the "constant effectiveness – minimum capacitance" methodology, the model may be used to model a device with any configuration of air streams (parallel flow, cross flow, counter flow, etc.) and may be used to model the sensible and latent aspects of an air to air heat exchanger, an enthalpy wheel, a hygroscopic heat exchanger or a permeable walled flat plate recuperator, among other devices.

Nomenclature

$\dot{m}_{fresh,in}$	[kg/hr]	Mass flow rate of air entering the "fresh air" side of the device.
$\dot{m}_{exhaust,in}$	[kg/hr]	Mass flow rate of air entering the "exhaust air" side of the device.
$\dot{m}_{fresh,out}$	[kg/hr]	Mass flow rate of air exiting the "fresh air" side of the device.
$\dot{m}_{exhaust,out}$	[kg/hr]	Mass flow rate of air exiting the "exhaust air" side of the device.
$\dot{m}_{\min}$	[kg/hr]	Minimum of the two air stream flow rates
$T_{fresh,in}$	[C]	Temperature of air entering the "fresh air" side of the device.
$T_{exhaust,in}$	[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.
$\omega_{exhaust,in}$	[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.
$\omega_{exhaust,out}$	[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.
$\dot{m}_{FreshToExhaust}$	[kg/hr]	Flow rate of moisture from the fresh air stream to the exhaust stream. This value is set to 0 if the flow of moisture is from the exhaust air stream to the fresh air stream.
$\dot{m}_{ExhaustToFresh}$	[kg/hr]	Flow rate of moisture from the exhaust air stream to the fresh stream. This value is set to 0 if the flow of moisture is from the fresh air stream to the exhaust air stream.
$h_{vapor,fresh,in}$	[kJ/kg]	Enthalpy of water vapor at the inlet of the fresh air stream
$h_{vapor,exhaust,in}$	[kJ/kg]	Enthalpy of water vapor at the inlet of the exhaust air stream
$\dot{m}_{MaxTransfer}$	[kg/hr]	Maximum possible moisture transfer between the air streams.
$C_{\min}$	[kJ/hr.K]	Minimum capacitance (mass flow rate times specific heat) air stream
$\dot{Q}_{tot,exhaust}$	[kJ/hr]	Energy transfer across the exhaust air stream.
$\dot{Q}_{tot,fresh}$	[kJ/hr]	Energy transfer across the fresh air stream.
$\dot{Q}_{sens}$	[kJ/hr]	Sensible energy transferred between air streams

$\dot{Q}_{lat}$	[kJ/hr]	Latent energy transferred between air streams
ε_{sens}	[0..1]	Sensible effectiveness of the device
ε_{lat}	[0..1]	Latent effectiveness of the device

Detailed Description

In an air to air heat recovery device, two streams of air are passed near each other in such a way as to make both energy and possibly mass transfer of moisture between the streams possible. Type667 models a heat recovery device 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 and latent effectiveness that must be supplied by the user. A schematic diagram of a counter flow air to air heat recovery unit is shown in Figure 1. A counter flow configuration has been chosen merely for the sake of diagram clarity.

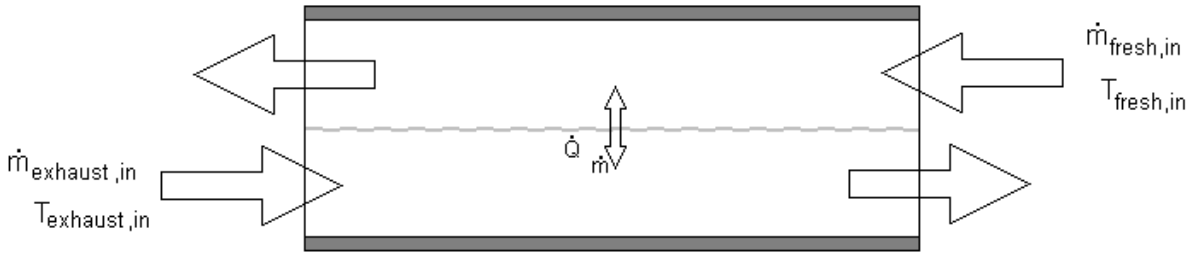


Figure 1: Air to Air Heat Recovery Device Schematic

For the purposes of this description, the two are streams will be called the "fresh air" stream and the "exhaust air" stream because commonly, an air to air heat recovery device is used to precondition outside (fresh) air that is to be mixed with zone return air and conditioned before being delivered back 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 permeable membrane that allows not only energy to transfer from one stream to the other but moisture to transfer as well.

Type667 first 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. 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. Having fully defined the entering air states, Type667 determines the sensible energy transferred between the two air streams using equation 667.1

$$\dot{Q}_{sens} = \varepsilon_{sens}\ C_{\min}\left(T_{exhaust,in} - T_{fresh,in}\right) \qquad \text{(Eq. 667.1)}$$

Where Cmin is the lesser product of mass flow rate and specific heat for each of the two streams. Type667 relies on a subroutine called AIRPROPS (distributed with this component) to determine a value of the specific heat of air that depends upon air temperature (in K).

Next, Type667 obtains the enthalpy of the water vapor at the inlet of each stream by calling the TRNSYS Steam Properties subroutine. The mass transfer of moisture from the exhaust air stream to the fresh air stream is given by equation 667.2.

$$\dot{m}_{transfer} = \varepsilon_{lat}\ \dot{m}_{\min}\left(\omega_{exhaust,in} - \omega_{fresh,in}\right) \qquad \text{(Eq. 667.2)}$$

In the above equation, m_{min} is the minimum of the two air flow rates. If the mass transfer is determined to be negative then moisture is being transferred from the fresh air stream to the exhaust air stream. Type667 reports these two transfers individually and always as a positive number instead of assigning a sign convention to the direction of moisture transfer. If moisture is transferred from the exhaust to the fresh air stream, the output giving moisture transfer in the opposite direction (fresh air stream to exhaust air stream) will be set to zero. The same holds in the opposite sense; if moisture is being transferred from the fresh air stream to the exhaust air stream then the output reporting moisture transfer from the exhaust air stream to the fresh air stream will be set to zero.

With the moisture transfer known, the enthalpies of the stream outlets can be determined using equations 667.3a and 667.3b.

$$h_{exhaust,out} = h_{exhaust,in} - \frac{\dot{Q}_{sens}}{\dot{m}_{exhaust}} + \dot{m}_{FreshToExhaust}\frac{h_{vapor,fresh,in}}{\dot{m}_{exhaust}} - \dot{m}_{ExhaustToFresh}\frac{h_{vapor,exhaust,in}}{\dot{m}_{exhaust}} \qquad \text{(Eq. 667.3a)}$$

$$h_{fresh,out} = h_{fresh,in} + \frac{\dot{Q}_{sens}}{\dot{m}_{fresh}} - \dot{m}_{FreshToExhaust}\frac{h_{vapor,fresh,in}}{\dot{m}_{fresh}} + \dot{m}_{ExhaustToFresh}\frac{h_{vapor,exhaust,in}}{\dot{m}_{fresh}} \qquad \text{(Eq. 667.3b)}$$

The outlet humidity ratios follow from equations 667.4a and 667.4b

$$\omega_{exhaust,out} = \omega_{exhaust,in} + \frac{\dot{m}_{FreshToExhaust}}{\dot{m}_{exhaust}} - \frac{\dot{m}_{ExhaustToFresh}}{\dot{m}_{exhaust}} \qquad \text{(Eq. 667.4a)}$$

$$\omega_{fresh,out} = \omega_{fresh,in} - \frac{\dot{m}_{FreshToExhaust}}{\dot{m}_{fresh}} + \frac{\dot{m}_{ExhaustToFresh}}{\dot{m}_{fresh}} \qquad \text{(Eq. 667.4b)}$$

The pressures (including pressure drop effects from the user supplied values), outlet enthalpies, and outlet humidity ratios are used in a call to PSYCHROMETRICS 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. In the saturated stream case, Type667 limits the amount of allowable mass transfer of vapor between streams to the value that results in saturation of one air stream and leaves the remainder of the vapor in the originating stream. To accomplish this, Type667 checks the actual transmission of water vapor for each stream using equations 667.5.

$$\dot{m}_{MaxTransfer} = MIN\left(\dot{m}_{exhaust}\left|\omega_{exhaust,in} - \omega_{exhaust,out}\right|, \dot{m}_{fresh}\left|\omega_{fresh,out} - \omega_{fresh,in}\right|\right) \qquad \text{(Eq. 667.5)}$$

Equations 667.3a and 667.3b are reevaluated with the value of $m_{MaxTransfer}$ calculated in equation 667.5 substituted for the appropriate value of either $m_{FreshToExhaust}$ or $m_{ExhaustToFresh}$ and the enthalpy values returned from the PSYCHROMETRICS routine. The outlet humidity ratios are similarly recalculated using equations 667.4a and b.

Finally, various energy transfer values are calculated. The total sensible energy transferred in the exhaust stream is given by equation 667.6

$$\dot{Q}_{tot,exhaust} = \dot{m}_{exhaust}\left(h_{exhaust,in} - h_{exhaust,out}\right) \quad \text{(Eq. 667.6)}$$

Likewise, the energy transferred in the fresh air stream is given by equation 667.7

$$\dot{Q}_{tot,fresh} = \dot{m}_{fresh}\left(h_{fresh,out} - h_{fresh,in}\right) \quad \text{(Eq. 667.7)}$$

The results of equations 667.6 and 667.7 should be identical as no other energy transfers are accounted for by the device. The latent energy transfer is given by equation 667.8

$$\dot{Q}_{latent} = \dot{Q}_{tot} - \dot{Q}_{sens} \quad \text{(Eq. 667.8)}$$

Where Q_{sens} is given by equation 667.1.

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