TYPE 664: ELECTRIC UNIT HEATER WITH VARIABLE SPEED FAN, PROPORTIONAL CONTROL, AND DAMPER CONTROL

General Description

Type664 models an electric unit heater whose fan speed, heating power, and fraction of outdoor air are proportionally and externally controlled. Proportional control indicates that these three variables can have any value between 0 and their rated values. External control indicates that the fraction of rated capacity, speed, or outdoor air is specified as a time dependent value by the user and is provided to the model as an input. The heater is designed not to exceed a user specified set point temperature. If at any point in the simulation the heater capacity and control signal would result in an outlet temperature higher than the set point, the external control signal value will be overridden. Fan power is specified as a polynomial relating normalized mass flow rate to normalized fan power. The user may also control the extent to which the fan power results in a temperature rise in the air stream.

Nomenclature

$\dot{P}_{fan}$	[kJ/hr]	Fan power at the current time step
$\dot{P}_{\max}$	[kJ/hr]	Maximum (rated) fan power
$c_0, c_1, c_2, etc.$	[-]	Coefficients of the polynomial relating normalized flow rate to normalized fan power
$\dot{m}_{air}$	[kg/hr]	Mass flow rate of air at the current time step
$\dot{m}_{\max}$	[kg/hr]	Maximum (rated) flow rate of air through the fan
$\dot{m}_{cond}$	[kg/hr]	Flow rate of condensate
$\dot{Q}_{air}$	[kJ/hr]	Energy added to the air stream by the fan and fan motor
γ_{fan}	[0..1]	Fan control signal – may have any value between 0 and 1
γ_{damper}	[0..1]	Damper setting – may have any value between 0 and 1
η_{motor}	[0..1]	Fan motor efficiency
f_{air}	[0..1]	Fraction of fan motor power that contributes to a temperature rise in the air stream.
$\omega_{air,primary}$	[kgH_2O/kgAir]	Humidity ratio of the primary air stream entering the mixing chamber of the unit heater. Normally this air would be recirculated indoor air.
$\omega_{air,secondary}$	[kgH_2O/kgAir]	Humidity ratio of the secondary air stream entering the mixing chamber of the unit heater. Normally this air would be outdoor makeup air.
$h_{air,primary}$	[kJ/kg]	Enthalpy of the primary air stream entering the mixing chamber of the unit heater. Normally this air would be recirculated indoor air.
$h_{air,secondary}$	[kJ/kg]	Enthalpy of the secondary air stream entering the mixing chamber of the unit heater. Normally this air would be outdoor makeup air.
$h_{air,FanOut}$	[kJ/kg]	Enthalpy of air exiting the fan before entering the heater
$h_{air,FanIn}$	[kJ/kg]	Enthalpy of air entering the fan (after mixing)
$h_{air,HtrOut}$	[kJ/kg]	Enthalpy of air exiting the heater (and exiting the unit heater)
$\dot{P}_{htr}$	[kJ/hr]	Maximum (rated) heater power
η_{htr}	[0..1]	Heater efficiency
γ_{htr}	[0..1]	Heater control signal – may have any value between 0 and 1

Detailed Description

Type664 models an electric unit heater with proportional heater control and a variable speed fan. It also contains a mixing damper that allows two air stream to be mixed before entering the heater. Temperature and either relative humidity or humidity ratio are inputs for each air stream and while most often one air stream would be indoor (recirculated) air and the other is outdoor (makeup) air, the user has complete control over the conditions of both air streams and is not limited by assumptions about the source of one stream or the other. The proportional control signal, the fan speed control signal, and the damper setting vary between 0 and 1 and are provided as inputs to the model. A schematic diagram of the electric unit heater is shown in Figure 1.

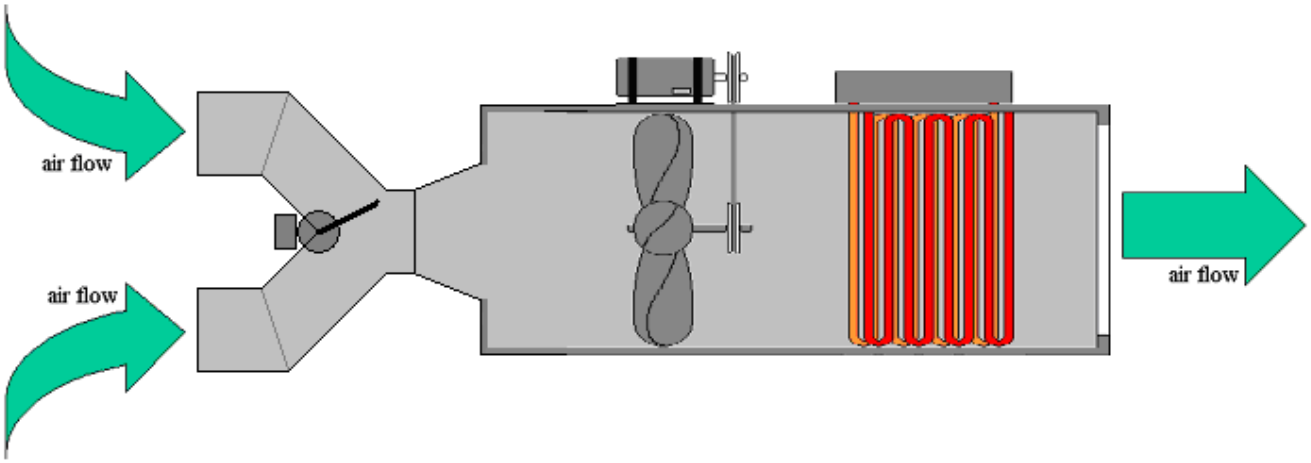


Figure 1: Electric Unit Heater Schematic

Type664 first performs a call to the TRNSYS psychrometrics routine in order to obtain those air properties for each inlet air stream 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, Type664 next mixes the two streams according to Equations 664.1a and b.

$$h_{air,FanIn} = \gamma_{damper} h_{air,primary} + (1-\gamma_{damper}) h_{air,secondary} \quad \text{(Eq. 664.1a)}$$

$$\omega_{air,FanIn} = \gamma_{damper} \omega_{air,primary} + (1-\gamma_{damper}) \omega_{air,secondary} \quad \text{(Eq. 664.1b)}$$

The flow rate of the mixed air stream is initially set to the rated value set as a parameter to the model. Mixing occurs at the user specified pressure of the primary (indoor) air stream as opposed to the pressure of the secondary (outdoor) air stream. This assumes that the dampers modulate to balance the pressures of the two inlet streams, that the user has provided a damper position that results in the correct flow rates and that the ambient pressure modulates to the inlet pressure. The psychrometrics routine is called once more to determine all properties of the mixed air. Often the procedure of converging on a mixed air state is iterative. Type664 calls PSYCHROMETRICS with pressure, enthalpy and humidity ratio. In return it gets temperature and modified values of humidity ratio and enthalpy. If the new

humidity ratio is lower than the previous humidity ratio, the air is determined to have been saturated (PSYCHROMETRICS sets humidity ratio back to the saturation line value if called with saturated conditions). STEAM_PROPS is called with the new air temperature to determine the enthalpy of the condensate (condensate is assumed to be at the mixed air temperature) and the enthalpy of the mixed air is calculated using Equation 664.2. If the enthalpy resulting from Equation 664.2 is within a tolerance of the mixed air enthalpy returned from the psychrometrics routine, the mixed air state has converged. If the enthalpy difference between 664.2 and PSYCHROMETRICS is not within the tolerance, the air enthalpy is updated to the new value and the procedure begins again. The mixed air state is also deemed to have converged if the procedure has iterated more than 50 times. Both the tolerance on enthalpy and the number of allowable iterations can be modified in the Fortran source code.

$$h_{air,FanIn} = \gamma_{damper} h_{air,primary} + \left(1-\gamma_{damper}\right) h_{air,\mathrm{sec}ondary} - h_{cond}\frac{\dot{m}_{cond}}{\dot{m}_{air}} \qquad \text{(Eq. 664.2)}$$

With the mixed air state fully determined, Type664 proceeds on to determine the amount of energy added to the air stream by the fan. The fan power at any given time step is determined based on a polynomial that expresses normalized power as a function of normalized flow rate as shown in Equation 664.3. The user may specify as many polynomial coefficients as desired among the Type's parameters. If a polynomial relating fan power to mass flow rate is unavailable, at least a value of c_0=0 and c_1=1 should be provided. With these coefficient values, the fan will draw its rated power at whatever speed it runs.

$$\dot{P}_{fan} = \dot{P}_{\max}\left(c_0 + c_1\frac{\dot{m}_{air}}{\dot{m}_{\max}} + c_2\left(\frac{\dot{m}_{air}}{\dot{m}_{\max}}\right)^2 + c_3\left(\frac{\dot{m}_{air}}{\dot{m}_{\max}}\right)^3 + \quad \ldots \right) \qquad \text{(Eq. 664.3)}$$

The energy transferred by the fan to the air stream is given by Equation 664.4.

$$\dot{Q}_{air} = \gamma_{fan}\dot{P}_{fan}\left(\eta_{motor} + \left(1-\eta_{motor}\right)f_{air}\right) \qquad \text{(Eq. 664.4)}$$

Where η_{fan} is the efficiency of the fan motor, γ_{fan} is the fan control signal and f_{air} is the fraction of the fan power that contributes to an air temperature rise across the fan. The fan control signal may have any value between 0 and 1 and is externally controlled (provided by the user as an input to the model) Through manipulation of f_{air}, the user is able to control whether the fan motor is in line with the fan and contained entirely within the air stream, or if the fan motor is mounted outside the electric unit heater in which case the energy associated with its inefficiency would affect the ambient but not the air stream itself. The energy transferred to the ambient by the fan motor is simply the difference between the fan power and the energy added to the air stream by the fan. With the energy transferred to the air stream by the fan known, the enthalpy of the air between the fan and heater is calculated using equation 664.5.

$$h_{air,FanOut} = h_{air,FanIn} + \frac{\dot{Q}_{air}}{\dot{m}_{air}} \qquad \text{(Eq. 664.5)}$$

It is important to note that Type664 assumes that the entire pressure rise specified as an input to the model is assumed to occur across the fan. The pressure drop across the heating coils is assumed to be negligible.

Energy is then added to the post fan air stream according to equation 664.6.

$$h_{air,HtrOut} = h_{air,FanOut} + \frac{\dot{P}_{htr}\eta_{htr}\gamma_{htr}}{\dot{m}_{air}} \quad \text{(Eq. 664.6)}$$

Where η_{htr} is the heater efficiency and γ_{htr} is the fan control signal. Again the control signal may have a value between 0 and 1 and is externally controlled. Thus it is possible that the electric unit heater may not be able to achieve its set point temperature if either the capacity or the control signal is insufficient. If the outlet state of the air is determined to be above the heater set point temperature, the heater control signal is internally adjusted so that the set point temperature is not exceeded. No check is made on the air condition between the fan and the heater as to whether the outlet temperature set point has been exceeded. It is therefore possible that the fan adds enough energy to the air stream that the outlet condition is exceeded, the heater is entirely OFF and the inlet condition does not exceed the set point condition.