TYPE 684: AIR SIDE ECONOMIZER

General Description

Type684 models an air side economizer that internally determines an appropriate mixture of outside and return air that will result in air delivered to the zone at the same temperature, enthalpy, or humidity ratio as air that would be delivered by a cooling coil.

Nomenclature

P_{amb}	[atm]	Absolute pressure of the ambient air entering the economizer.
P_{zone}	[atm]	Absolute pressure of the air in the conditioned zone. Note this value is also the pressure of return air entering the economizer.
ΔP_{oa}	[atm]	Pressure drop across the outside air damper
ΔP_{exh}	[atm]	Pressure drop across the exhaust air damper
ΔP_{cont}	[atm]	Pressure drop across the control damper.
T_{amb}	[ºC]	Temperature of ambient air entering the economizer
T_{zone}	[ºC]	Temperature of zone air. Note this is also the temperature of return air entering the economizer.
$T_{zone,set}$	[ºC]	Zone set point temperature
$T_{coil,set}$	[ºC]	Coil set point temperature (the minimum temperature of mixed air that should be delivered to the zone)
RH_{amb}	[%]	Relative humidity of ambient air
RH_{zone}	[%]	Relative humidity of zone air
$RH_{zone,set}$	[%]	Relative air humidity set point of the zone.
$RH_{coil,set}$	[%]	Relative humidity set point of air exiting the coil.
ω_{amb}	[kgH_2O/kgAir]	Absolute humidity ratio of ambient air.
$\omega_{amb(corr)}$	[kgH_2O/kgAir]	Corrected (for saturated conditions) absolute humidity of ambient air.
ω_{zone}	[kgH_2O/kgAir]	Absolute humidity ratio of zone air.
$\omega_{zone(corr)}$	[kgH_2O/kgAir]	Corrected (for saturated conditions) absolute humidity of zone air.
$\omega_{zone,set}$	[kgH_2O/kgAir]	Absolute humidity ratio set point for zone air.
$\omega_{zone,set(corr)}$	[kgH_2O/kgAir]	Corrected (for saturated conditions) absolute humidity ratio set point for zone air.
$\omega_{coil,set}$	[kgH_2O/kgAir]	Absolute humidity ratio set point for air exiting the coil.
$\omega_{coil,set(corr)}$	[kgH_2O/kgAir]	Corrected (for saturated conditions) absolute humidity ratio set point for air exiting the coil.
h_{amb}	[kJ/kg]	Enthalpy of outdoor air
h_{zone}	[kJ/kg]	Zone air enthalpy
$h_{zone,set}$	[kJ/kg]	Zone air enthalpy set point
h_{coil}	[kJ/kg]	Enthalpy of air exiting the coil
$\dot{m}_{oa}$	[kg/hr]	Mass flow rate of outside air entering the economizer.
$\dot{m}_{spply}$	[kg/hr]	Mass flow rate of supply air to the zone.

$\dot{m}_{ret}$	[kg/hr]	Mass flow rate of return air entering the economizer.
$f_{oa,\min}$	[0..1]	The minimum allowable fraction of outside air that may be used by the economizer.
$f_{oa,\max}$	[0..1]	The maximum allowable fraction of outside air that may be used by the economizer.
f_{oa}	[0..1]	Fraction of outside air at the current time
$\dot{Q}_{oa}$	[kJ/hr]	Energy drawn from outside air
$\dot{Q}_{saved}$	[kJ/hr]	Amount of energy saved by using the economizer.

Detailed Description

Typically, building codes require that a certain amount of ventilation air be provided to occupants of the building. Furthermore, code often requires that a certain amount of that ventilation air must be fresh air drawn from outside the building. The remainder of the ventilation air may be recirculated from the conditioned zones and mixed with outside air. Depending upon outdoor and indoor conditions, significant energy savings can be attained by mixing more than the minimum mandated amount of outdoor air with return air. If the outdoor air temperature is above the conditioned zone set point temperature, it is best to provide only the minimum required amount of outdoor air in order to minimize the load on the air conditioning cooling coil. If the outdoor air temperature is below the zone set point temperature, then more outside air should be brought in so as to reduce the load on the coil. The desired temperature of mixed air is the temperature of the building's cooling coil. If the mixed air temperature is below the cooling coil temperature then reheating must occur in order to maintain occupant comfort. An air side economizer is a device designed to modulate the proportion of return and outside air automatically to reduce load on the building's cooling coil. A air side economizer is shown schematically in Figure 1.

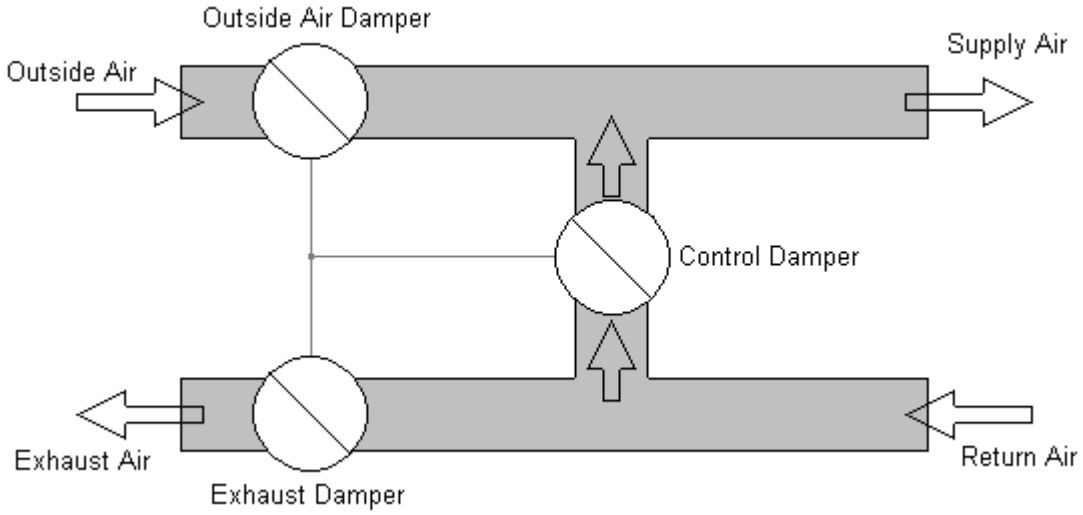


Figure 1: Side Economizer Schematic

In Figure 1, the lines connecting the outside air damper, the control damper and the exhaust damper are meant to indicate that the three dampers are controlled together so as to supply the desired mixed supply air conditions.

As inputs, Type684 takes outside air conditions of temperature, pressure, and either relative humidity or absolute humidity ratio. It also takes zone (return) air temperature, pressure and either relative humidity or absolute humidity ratio. The Type684 economizer can be configured (using parameter 2) to determine an appropriate fraction of outdoor air based on zone temperature, zone humidity ratio, or zone air enthalpy. In order to maintain zone set points, the model must also be provided with the zone temperature setting and either the zone humidity ratio setting or the zone relative humidity setting as well as the cooling coil temperature setting and either the cooling coil relative humidity or absolute humidity ratio. These last two values are used to set an upper limit on the amount of outside air brought in; if the temperature of outside air is lower than the cooling coil temperature and all outside air is brought in, then the ventilation air provided to the occupants is likely going to be colder than comfortable. The lowest temperature air that one would want to provide to the occupants is air at the temperature of the cooling coil. The last set of inputs required are the quantity of supply air as well as the minimum and maximum allowable outside air fractions. Type684 also takes a control signal input that turns ON and OFF the economizer. However, the control signal is overridden in order to continually provide the minimum allowable flow of outdoor air to the building occupants.

Each time that Type684 is called, it fully determines the outdoor air state, the return air state, the exhaust air state, the supply air state and the cooling coil air state through calls to the TRNSYS Psychrometrics utility routine. In each case, the Psychrometrics routine is called with pressure, temperature, and either relative humidity or absolute humidity ratio. If the Psychrometrics routine is called with an absolute humidity ratio greater than the saturation humidity ratio for the specified temperature, the humidity ratio will be reset to the saturation humidity ratio and a warning will be printed to the simulation log and list files. For each of the air states, the Psychrometrics routine returns the air pressure, temperature, relative humidity, humidity ratio and enthalpy. Table 1 shows the variables used in each of the five calls to the Psychrometrics routine as well as the values returned.

Table 1: Economizer Air States

Air State	Conditions used in call to Psychrometrics	Values returned by Psychrometrics
Outdoor air conditions	Pressure: $P_{amb} - \Delta P_{oa}$ Temperature: T_{amb} Humidity: RH_{amb} or ω_{amb}	Pressure: $P_{amb} - \Delta P_{oa}$ Temperature: T_{amb} Humidity: RH_{amb} and $\omega_{amb(corr)}$ Enthalpy: h_{amb}
Return air conditions	Pressure: $P_{zone} - \Delta P_{cont}$ Temperature: T_{zone} Humidity: RH_{zone} or ω_{zone}	Pressure: $P_{zone} - \Delta P_{cont}$ Temperature: T_{zone} Humidity: RH_{zone} and $\omega_{zone(corr)}$ Enthalpy: h_{zone}
Exhaust air conditions	Pressure: $P_{zone} - \Delta P_{exh}$ Temperature: T_{zone} Humidity: RH_{zone} or ω_{zone}	Pressure: $P_{zone} - \Delta P_{exh}$ Temperature: T_{zone} Humidity: RH_{zone} and $\omega_{zone(corr)}$ Enthalpy: h_{zone}
Zone air conditions	Pressure: P_{zone} Temperature: $T_{zone,set}$ Humidity: $RH_{zone,set}$ or $\omega_{zone,set}$	Pressure: P_{zone} Temperature: $T_{zone,set}$ Humidity: $RH_{zone,set}$ and $\omega_{zone,set(corr)}$ Enthalpy: $h_{zone,set}$
Cooling Coil air conditions	Pressure: $MIN(P_{zone} - \Delta P_{cont}, P_{amb} - \Delta P_{oa})$ Temperature: $T_{coil,set}$	Pressure: $MIN(P_{zone} - \Delta P_{cont}, P_{amb} - \Delta P_{oa})$ Temperature: $T_{coil,set}$

	Humidity: $RH_{coil,set}$ or $\omega_{coil,set}$	Humidity: $RH_{coil,set}$ and $\omega_{coil,set(corr)}$ Enthalpy: h_{coil}

When the economizer is fully OFF (the supply flow rate of air is set to zero) then the values determined by this model as outputs are readily calculable. The flow rate of outside air is set to zero as are the flow rates of return air and exhaust air. The pressure of the mixed (supply air) is set to the pressure of the return air. The temperature, relative humidity, enthalpy and humidity ratio of supply air are set to their corresponding return air values as well.

If, on the other hand, a non zero value of supply air flow rate has been provided then two special case situations are first checked. Regardless of the value of the economizer control signal and depending upon the economizer mode (parameter 2) if the temperature of outside air is greater than the zone set temperature (economizer mode 1) or if the enthalpy of outdoor air is greater than the zone set point enthalpy (economizer mode 2) or if the humidity ratio of outdoor air is greater than the zone set point humidity ratio (economizer mode 3) then it is desirable to bring in as little outdoor air as possible. Under any of the above circumstances, any amount of outside air brought in will increase the load on the coil. The economizer control signal is overridden because the user supplied minimum amount of outdoor air must still be supplied to the space. Under this first special case the amount of outside air is given by equation 684.1

$$\dot{m}_{oa} = \dot{m}_{spply}\ f_{oa,\min} \qquad \text{(Eq. 684.1)}$$

The corresponding amount of return air is given by 684.2

$$\dot{m}_{ret} = \dot{m}_{spply} - \dot{m}_{oa} \qquad \text{(Eq. 684.2)}$$

Basic mixing equations provide the mixed air humidity ratio and enthalpy as shown in equations 684.3a and 684.3b in which the humidity ratio of return air is the humidity ratio of the zone from which it is drawn.

$$\omega_{mix} = \frac{\left(\omega_{oa}\ \dot{m}_{oa} + \omega_{ret}\ \dot{m}_{ret}\right)}{\dot{m}_{spply}} \qquad \text{(Eq. 684.3a)}$$

$$h_{mix} = \frac{\left(h_{oa}\ \dot{m}_{oa} + h_{ret}\ \dot{m}_{ret}\right)}{\dot{m}_{spply}} \qquad \text{(Eq. 684.3b)}$$

The air is supplied at the minimum of the outdoor air and return pressures and the Psychrometrics routine is again called to fully determine the mixed air state.

In the second special case, the outdoor air is below the zone set point but is above the coil set point. Again depending upon the economizer mode, outdoor air temperature, enthalpy, or humidity ratio will be compared with coil set point temperature, enthalpy, or humidity ratio. Under these circumstances, the greatest reduction in coil load will be seen by bringing in as much outdoor air as possible – either 100% or the user defined maximum fraction. Equation 684.4 gives the flow rate of outdoor air under this second special case.

$$\dot{m}_{oa} = \dot{m}_{spply}\ f_{oa,\max} \qquad \text{(Eq. 684.4)}$$

Equations 684.2, 684.3a, and 684.3b still hold for calculating the amount of return air and the mixed air properties.

If neither of the two special cases is true, then the outdoor air is below the cooling coil set point condition and some fraction of outdoor air between the minimum and maximum allowable values can be mixed with return air in order to provide the required cooling coil condition air to the zone. Type684 performs an iterative search starting with the assumption that the minimum allowable fraction of outdoor air will be provided. At each iteration, the mass flow of outdoor air and return air are calculated, the air streams are mixed and the Psychrometrics routine is called to fully determine the mixed air state and appropriate mixed air property (temperature, enthalpy, or humidity ratio) is compared with the corresponding cooling coil set point. If the air property matches the set point, then the correct amount of outdoor air has been found and iteration stops. If the mixed air property is above the set point then more outside air can be brought in. The fraction of outdoor air is increased by a dimensionless delta fraction that is specified in the Type684 Fortran code. The default value of this fraction step size is 0.0001. If that value is inappropriate it may be changed in the code – changing the value requires that the code be recompiled and relinked into the appropriate DLL. Smaller step sizes will result in a more precise fraction of outside air but will slow the iterative search process down, increasing simulation run time.

As soon as the appropriate fraction of outdoor air has been determined, Type684 calculates two energy flows: the amount of energy from the outside air is given by equation 684.5.

$$\dot{Q}_{oa} = \dot{m}_{spply}\left(h_{ret} - h_{mix}\right) \qquad \text{(Eq. 684.5)}$$

And the amount of energy saved by using the economizer is given by equation 684.6.

$$\dot{Q}_{saved} = \left(f_{oa} - f_{oa,\min}\right)\dot{m}_{spply}\left(h_{ret} - h_{oa}\right) \qquad \text{(Eq. 684.6)}$$