TYPE 506: DIRECT EVAPORATIVE COOLER (SWAMP COOLER)

General Description

Type506 models an evaporative cooling device for which the user supplies the inlet air conditions and the saturation efficiency and the model calculates the outlet air conditions. The cooling process is assumed to be a constant wet bulb temperature process meaning that air enters and exits at the same wet bulb temperature. The device is not equipped with controls that monitor the conditions of the outlet air. When the device is ON (based on a user supplied control signal value), Type506 cools the air as much as it can given the entering conditions and the device efficiency. If a controlled evaporative cooling device is more appropriate to the user's circumstances, Type507 may be used. Type507 models a similar direct evaporative cooling device but takes a target air outlet relative humidity.

Nomenclature

T_{AirOut}	[ºC]	Dry bulb temperature of air exiting the device.
$T_{Air,in}$	[ºC]	Dry bulb temperature of air entering the device
$T_{\min,AirOut}$	[ºC]	Minimum dry bulb temperature of air exiting the device
$T_{wetbulb,AirIn}$	[ºC]	Wet bulb temperature of air entering the device
T_{wbd}	[ºC]	Wet bulb depression (the maximum temperature difference possible between inlet and outlet dry bulb air temperature)
$\dot{Q}_{air}$	[kJ/hr]	Energy transferred to or removed from the air stream.
$\dot{m}$	[kg/hr]	Mass flow rate of air through the device
h_{AirIn}	[kJ/kg]	Enthalpy of air entering the device
h_{AirOut}	[kJ/kg]	Enthalpy of air exiting the device
$\eta_{saturation}$	[0..1]	Saturation efficiency of the evaporative cooling process

Detailed Description

An evaporative cooler (sometimes called a swamp cooler) is a device that cools air by passing it across a wet medium. Such devices can be found in many configurations ranging from those in which air is passed across a solid matrix that contains water (such as a wet sponge or filter) or in which air passes directly over an open tray of water. As hot air passes over the wet media, some of its energy goes to evaporating water from the media. The air comes out of the other side of the device having given up some of its energy and consequently, exits at a lower temperature and a higher humidity. Figure 1 shows a schematic diagram of a possible evaporative cooler configuration.

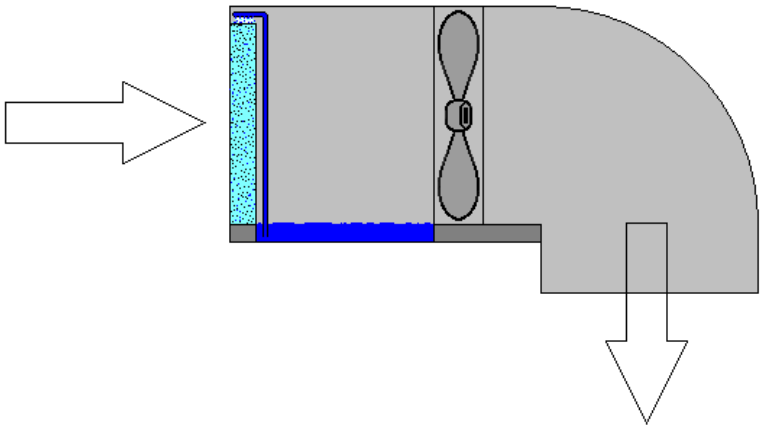


Figure 1: Evaporative Cooler Schematic

Evaporative cooling devices can be broken into two groups: direct and indirect. Direct devices contain a single air stream that is passed through or across the wetted media. Indirect devices involve two air streams in which the primary air stream []. Additionally, evaporative cooling devices may either be controlled or uncontrolled. In an uncontrolled device, air passes across the wetted media at a rate set by a fan. The flow rate is not modulated in any way and the air comes out at a state determined entirely by the inlet air conditions and the effectiveness of the device. In a controlled evaporative cooler, some aspect of the outlet air is monitored and the flow rate of air through the device is modulated to try and achieve the desired state. The minimum outlet temperature that can be achieved by the device is limited by the incoming wet bulb temperature as indicated by equation 506.1.

$$T_{\min,AirOut} = T_{wetbulb,AirIn} \qquad \text{Eq. 506.1}$$

Based on equation 506.1, it can be seen that direct, uncontrolled evaporative coolers are limited in their performance primarily by how dry the incoming air is. The drier the incoming air, the lower the minimum possible outlet air temperature. This component (Type506) models an uncontrolled, direct evaporative cooler whose performance is based on a user defined saturation efficiency. Type506 has both an input for the inlet air flow rate and for the device control signal. The two are not interconnected meaning that air can pass through the device without being cooled through evaporation.

When air is passing through the evaporative cooler and whether or not the control signal input is set to ON (active evaporative cooling), the component calls the TRNSYS Psychrometrics routine to fully determine the state of the inlet air. Depending upon the Type506 mode of operation, the user must specify inlet air pressure, temperature, and either relative humidity or humidity ratio. The Psychrometrics routine returns the inlet air wet bulb temperature and enthalpy as well as parroting back the inlet temperature, pressure, relative humidity and humidity ratio. If the inlet conditions sent to Psychrometrics were such that the inlet air is saturated, the returned wet bulb temperature, relative humidity and humidity ratio will correspond to the saturated air condition at the inlet temperature. If this situation arises and Psychrometrics modifies the inlet air condition, the user will find a warning printed in the simulation log and list files.

When active evaporative cooling is OFF (control signal set to 0) but air is flowing through the device the temperature and humidity ratio of the outlet air are set to the respective inlet air conditions. The outlet air pressure is determined by subtracting the user specified device pressure drop from the air inlet pressure. The humidity ratio of the outlet air is set to the humidity ratio of the inlet air and the

Psychrometrics routine is called once more with pressure and humidity ratio to fully determine the outlet state. Because of the pressure drop across the device (which can be significant if the air is being forced through a wetted matrix), the enthalpy of air exiting the device may be different from the enthalpy of air entering the device. The corresponding energy removed from the air stream to evaporate water under these circumstances is given by equation 506.2.

$$\dot{Q}_{air} = \dot{m}\left(h_{AirIn} - h_{AirOut}\right) \qquad \text{Eq. 506.2}$$

When active evaporative cooling is ON, and there is air flowing through the device, the minimum temperature at which air can exit the device is calculated using equation 506.1. This value is also known as the device's wet bulb depression. The temperature of outlet air is given by equation 506.3

$$T_{AirOut} = T_{Air,in} - \eta_{saturation}\ T_{wbd} \qquad \text{Eq. 506.3}$$

Where T_{wbd} is the wet bulb depression and $\eta_{saturation}$ is the efficiency with which the device operates. The wet bulb temperature of the air entering and exiting the device is assumed to be constant in other evaporative cooling applications it may be more appropriate to assume that the process follows lines of constant enthalpy as opposed to lines of constant wet bulb temperature on a psychrometric chart. The Psychrometrics routine is called with the outlet dry bulb and wet bulb temperatures. Outlet relative humidity, humidity ratio and enthalpy are returned. The energy transferred to the air stream in the device is again given by equation 506.2. The power drawn by the device is very simply set to the user specified value whenever the active cooling control signal is set to ON.