TYPE 680: SINGLE-EFFECT HOT WATER-FIRED ABSORPTION CHILLER

General Description

Type680 uses a normalized catalog data lookup approach to model a single-effect hot-water fired absorption chiller. “Hot Water-Fired” indicates that the energy supplied to the machine’s generator comes from a hot water stream. Because the data files are normalized, the user may model any size chiller using a given set of data files. Example files are provided. Type680 was made a standard TRNSYS Component (Type107) with the release of TRNSYS 16.

Nomenclature

$Capacity$	[kJ/hr]	Mass flow rate of air entering the “fresh air” side of the device.
$f_{FullLoadCapacity}$	[0..1]	Fraction of the device’s full load capacity during operation under current conditions.
$f_{NominalCapacity}$	[0..1]	Fraction of the device’s nominal capacity during operation under current conditions.
$Capacity_{Rated}$	[kJ/hr]	Rated cooling capacity of the device
$\dot{Q}_{remove}$	[kJ/hr]	Amount of energy that must be removed from the chilled water stream in order to reach the set point temperature
$T_{chw,set}$	[ºC]	“Chilled water” stream set point.
f_{design}	[0..1]	Fraction of design capacity at which the machine is currently operating.
COP_{Rated}	[-]	Machine’s rated Coefficient of Performance.
$f_{DesignEnergyInput}$	[0..1]	Fraction of design energy input currently required by the machine.
$T_{hw,out}$	[ºC]	Temperature of fluid exiting the “hot water” stream
$T_{hw,in}$	[ºC]	Temperature of fluid entering the “hot water” stream
$\dot{Q}_{hw}$	[kJ/hr]	Energy removed from the “hot water” stream
$\dot{m}_{hw}$	[kg/hr]	Mass flow rate of the “hot water” stream fluid
Cp_{hw}	[kJ/kg.K]	Specific heat of the “hot water” stream fluid.
$T_{chw,out}$	[ºC]	Temperature of fluid exiting the “chilled water” stream
$T_{chw,in}$	[ºC]	Temperature of fluid entering the “chilled water” stream
$\dot{Q}_{chw}$	[kJ/hr]	Energy removed from the “chilled water” stream
$\dot{m}_{chw}$	[kg/hr]	Mass flow rate of the “chilled water” stream fluid
Cp_{chw}	[kJ/kg.K]	Specific heat of the “chilled water” stream fluid.
$T_{cw,out}$	[ºC]	Temperature of fluid exiting the “cooling water” stream
$T_{cw,in}$	[ºC]	Temperature of fluid entering the “cooling water” stream
$\dot{Q}_{cw}$	[kJ/hr]	Energy added to the “cooling water” stream
$\dot{m}_{cw}$	[kg/hr]	Mass flow rate of the “cooling water” stream fluid
Cp_{cw}	[kJ/kg.K]	Specific heat of the “cooling water” stream fluid.
$\dot{Q}_{aux}$	[kJ/hr]	Energy draw of parasitics (solutions pumps, controls, etc.)
COP	[-]	Coefficient of Performance for the device.

Detailed Description

In a "conventional" refrigeration cycle, refrigerant returns as low pressure vapor (ideally near the saturated vapor point) from the evaporator. This vapor then passes through an electrically driven compressor in which it is turned into a higher pressure gas before being passed to the condenser. Both the work of pressurizing the vapor and the work of pumping the refrigerant around the loop is done by the an electrically driven compressor. In a "single effect" absorption machine, the refrigerant vapor (typically water) returning from the evaporator is absorbed in a medium (often aqueous ammonia or lithium bromide) and is cooled to a liquid state, rejecting its heat to a cooling fluid stream. This liquid is then pumped into a device called a generator, where heat is added from a hot water stream to desorb the refrigerant from its solution. Once the refrigerant is revaporized, it enters the condenser and follows a standard refrigerant cycle (condenser, expansion valve, evaporator). A single effect absorption cycle is shown schematically in Figure 1.

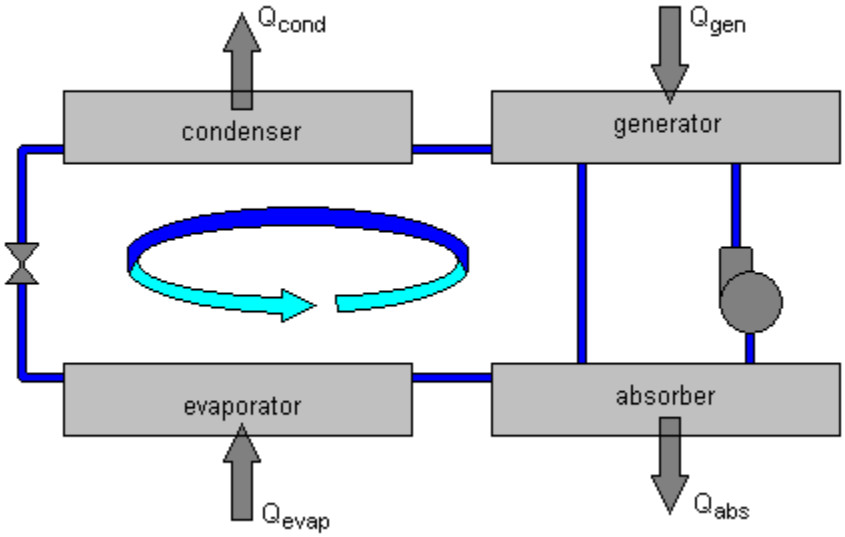


Figure 1: Single-Effect Absorption Chiller Device Schematic

The benefit of an absorption refrigerant cycles is that the energy required to pump the liquid refrigerant from a low pressure in the absorber to a higher pressure in the generator is comparatively small and the remainder of the work (liquefying and vaporizing the refrigerant) can be accomplished with heat instead of electricity. This fact makes absorption chillers especially valuable in cogeneration systems where waste heat from steam and other processes is abundant.

Type680 uses a catalog data lookup approach to predict the performance of a single effect, hot water fired absorption chiller. In this design, the heat required to desorb the refrigerant is provided by a stream of hot water. The energy of the refrigerant absorption process is rejected to a cooling water stream and the machine is designed to chill a third fluid stream to a user designated set point temperature. Because of the catalog data lookup approach, Type680 is not applicable over every range of inlet conditions. As with other components that rely on catalog data, the performance of the machine can be predicted and interpolated within the range of available data but cannot be extrapolated beyond the range. One beneficial feature to this model is that the data, taken directly from manufacturer's catalogs available online is normalized so that once a data file has been created, it may be used to model absorption machines other than the specific size for which the data was intended. In creating example data files for distribution with this component, the developers noted that there was very little variability between data

files once they were normalized. Using normalized data and the model's first two parameters (design coefficient of performance and design capacity) the user can adjust the size of the machine being modeled to whatever is appropriate to the system being simulated.

Type107 requires a single data file, which is to be specified in the standard TRNSYS data format. Since example data files are included with this component, every effort should be made to preserve the syntactical format of the data. An example file is located in:

.\TESS Models\SampleCatalogData\AbsorbtionChillers\SingleEffect\HotWater-Fired\ S1.dat.

The file contains values of normalized fraction of full load capacity and fraction of design energy input for various values of fraction of design load (-) chilled water set point temperature (ºC) entering cooling water temperature (ºC) and entering hot water temperature (ºC).

Upon determining that the absorption chiller is ON based on the value of the control signal, Type680 first determines the fraction of design load at which it must operate first by calculating the amount of energy that must be removed from the chilled water stream in order to bring it from its entering temperature to the set point temperature as shown in equation 680.1

$$\dot{Q}_{remove} = \dot{m}_{chw} Cp_{chw} \left(T_{chw,in} - T_{chw,set} \right) \qquad \text{(Eq. 680.1)}$$

The required energy removal is then divided by the machine's capacity (parameter 1) to determine the fraction of design load at which the machine is required to operate.

$$f_{DesignLoad} = \frac{\dot{Q}_{remove}}{Capacity_{Rated}} \qquad \text{(Eq. 680.2)}$$

Type680 then calls the TRNSYS Dynamic Data subroutine with the user specified hot water inlet temperature, cooling water inlet temperature, chilled water set point temperature, and fraction of design load. Dynamic Data reads the user specified data file and returns values of the fraction of the machine's rated capacity that is available given the hot water entering temperature. This reduced capacity is called the nominal capacity as opposed to the rated capacity. The capacity of the machine at any given time, therefore is given by equation 680.3.

$$Capacity = f_{FullLoadCapacity} * f_{NominalCapacity} Capacity_{Rated} \qquad \text{(Eq. 680.3)}$$

Dynamic Data also returns the machine's fraction of design energy input for the current conditions. When operating at rated capacity, the design energy input must be provided to the chiller in order for it to operate. When the chiller is running at part load, only a fraction of the design energy input is required. With this value returned by Dynamic Data, the energy delivered to the chiller by the hot water stream can be calculated using equation 680.4.

$$\dot{Q}_{hw} = \frac{Capacity_{Rated}}{COP_{Rated}} f_{DesignEnergyInput} \qquad \text{(Eq. 680.4)}$$

The hot water stream outlet temperature is then

$$T_{hw,out} = T_{hw,in} - \frac{\dot{Q}_{hw}}{\dot{m}_{hw} Cp_{hw}} \quad \text{(Eq. 680.5)}$$

The chilled water outlet temperature, which should be the set point temperature but may be greater if the machine is capacity limited, is then calculated as:

$$T_{chw,out} = T_{chw,in} - \frac{MIN\left(\dot{Q}_{remove}, Capacity\right)}{\dot{m}_{chw} Cp_{chw}} \quad \text{(Eq. 680.6)}$$

In order for energy to balance in the device, the energy rejection to the cooling water stream is given by 680.7

$$\dot{Q}_{cw} = \dot{Q}_{chw} + \dot{Q}_{hw} + \dot{Q}_{aux} \quad \text{(Eq. 680.7)}$$

The term Q_{aux} accounts for the energy consumed by the various parasitics in the system such as solution pumps, fluid stream pumps, controls. The auxiliary energy requirement of the device is specified among the model's parameters. Type680 assumes that the entire auxiliary energy requirement is used whenever the device is in operation, regardless of whether or not it is operating at full capacity.

Lastly, the temperature of the exiting cooling water stream can be calculated using equation 680.8.

$$T_{cw,out} = T_{cw,in} + \frac{\dot{Q}_{cw}}{\dot{m}_{cw} Cp_{cw}} \quad \text{(Eq. 680.8)}$$

The device COP is defined as shown in equation 680.9

$$COP = \frac{\dot{Q}_{chw}}{\dot{Q}_{aux} + \dot{Q}_{hw}} \quad \text{(Eq. 680.9)}$$