TYPE 679: SINGLE-EFFECT STEAM-FIRED ABSORPTION CHILLER

General Description

Type679 uses a normalized catalog data lookup approach to model a single-effect steam-fired absorption chiller. "Steam-Fired" indicates that the energy supplied to the machine's generator comes from a steam source. Because the data files are normalized, the user may model any size chiller using a given set of data files. Example files are provided.

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 from the evaporator (ideally near the saturated gas line of the vapor dome). This vapor then passes through an electrically driven compressor where 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 through the system is done by the compressor. In a "single effect" absorption machine, the refrigerant (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 an energy source to desorb the refrigerant from its solution. In a "steam fired" chiller, the energy source is steam. 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.

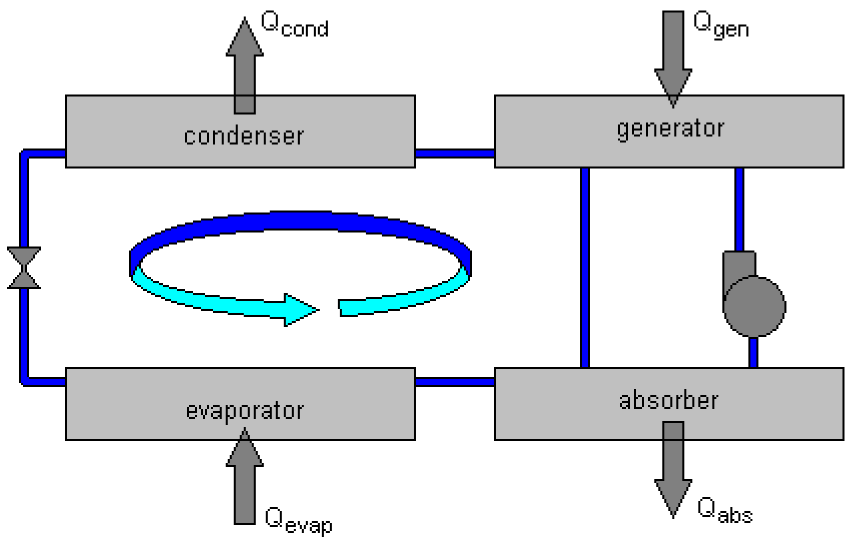

Figure 1: Single-Effect Absorption Chiller Device Schematic

The benefit of an absorption refrigerant cycles is that the energy required to pump the fluid from a low pressure in the absorber to a higher pressure in the generator is comparatively small and the remainder of the work (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.

Type679 uses a catalog data lookup approach to predict the performance of a single effect, steam water fired absorption chiller. In this design, the heat required to desorb the refrigerant is provided by a steam source. 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, Type679 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. Apart from the advantage that a catalog data based model relies not on difficult to find physical constants but on easily obtainable manufacturer's catalogs, the data 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.

Type679 requires two data files, each 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. The first file (example in: \Catalog_Data\ABSCHLs\Single-Effect\Steam-Fired\Sample\S1.dat) contains values of normalized fraction of full load capacity (dimensionless units) and values of the fraction of design energy input (dimensionless units) for various values of fraction of design load (dimensionless units), chilled water set point (in ºC), entering cooling water temperature (in ºC), and entering steam gauge pressure (in kPa). The second data file (example located in: \Catalog_Data\ABSCHLs\Single-Effect\Steam-Fired\Sample\S2.dat) provides values of condensate drain temperature (in ºC) for various values of steam inlet gauge pressure (in kPa). In essence the first data file provides the user with the machine's nominal capacity and required energy input given the conditions of the steam source while the second provides information about the state of the condensate that drains from the steam source.

Upon determining that the absorption chiller is ON based on the value of the control signal, Type679 first calls the TRNSYS Steam Properties routine to fully determine the inlet state of the steam. Type679 requires that the user provide values of steam inlet temperature and pressure. The Steam Properties routine returns the entering steam's enthalpy and quality. Since catalog data assumes that saturated steam is provided to the steam source, if the returned quality of the entering steam is less than 1 then Type679 recalls the Steam Properties routine with the user specified inlet pressure and a quality of 1. The inlet temperature will be reset to insure that saturated steam enters the absorption chiller. The user is warned if the temperature was reset. Care should be taken to look in the list file for such warnings, even after a simulation that reports no errors.

Type679 next calculates the amount of energy required to bring the user specified inlet chilled water temperature to its set point temperature using equation 679.1.

$$\dot{Q}_{remove} = \dot{m}_{chw} Cp_{chw} \left(T_{chw,in} - T_{chw,set} \right) \quad \text{(Eq. 679.1)}$$

The fraction of design load can now be determined using equation 679.2.

$$f_{DesignLoad} = \frac{\dot{Q}_{remove}}{Capacity_{Design}} \quad \text{(Eq. 679.2)}$$

With the fraction of design load known, Type679 next calls the TRNSYS Dynamic Data subroutine with this value as well as with the user specified values chilled water set point, entering cooling water temperature, and entering steam gauge pressure. Dynamic Data reads the appropriate data file and returns the fraction of the machine's rated capacity that is available and the fraction of the design energy input that is required given the entering conditions. The current available capacity is referred to as the machine's nominal capacity and is given by equation 679.3.

$$Capacity = f_{FullLoadCapacity} * Capacity_{Rated} \quad \text{(Eq. 679.3)}$$

In order to determine the conditions of the steam source at the absorption chiller's outlet, Dynamic Data is called a second time, this time referencing the second data file. Dynamic Data returns the condensate temperature that corresponds to the steam inlet pressure. With this value in hand and assuming an exit quality of 0 (saturated liquid), Type679 calls the Steam Properties routine again to fully determine the condensate outlet conditions (enthalpy and pressure). Various quantities can now be computed.

The energy delivered to the chiller by the steam source is calculated using equation 679.4

$$\dot{Q}_{steam} = \frac{Capacity_{Rated}}{COP_{Rated}} f_{DesignEnergyInput} \quad \text{(Eq. 679.4)}$$

where $f_{\text{DesignEnergyInput}}$ is one of the values returned by the first call to Dynamic Data and is the value specified in the second column of the example S1 data file.

The flow rate of steam required to meet the current load at current conditions is given by equation 679.5.

$$\dot{m}_{steam} = \frac{\dot{Q}_{steam}}{\left(h_{steam,in} - h_{cond,out}\right)} \quad \text{(Eq. 679.5)}$$

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

$$T_{chw,out} = T_{chw,in} - \frac{MIN\left(\dot{Q}_{remove}, Capacity\right)}{\dot{m}_{chw} Cp_{chw}} \quad \text{(Eq. 679.6)}$$

In order for energy to balance in the device, the energy rejection to the cooling water stream is given by 679.7

$$\dot{Q}_{cw} = \dot{Q}_{chw} + \dot{Q}_{steam} + \dot{Q}_{aux} \quad \text{(Eq. 679.7)}$$

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. Type679 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 679.8.

$$T_{cw,out} = T_{cw,in} + \frac{\dot{Q}_{cw}}{\dot{m}_{cw} Cp_{cw}} \quad \text{(Eq. 679.8)}$$

The device COP is defined as shown in equation 679.9

$$COP = \frac{\dot{Q}_{chw}}{\dot{Q}_{aux} + \dot{Q}_{steam}} \quad \text{(Eq. 679.9)}$$