TYPE 681: SINGLE-EFFECT DIRECT-FIRED ABSORPTION CHILLER

General Description

Type681 uses a normalized catalog data lookup approach to model a single-effect direct fired absorption chiller. "Direct Fired" indicates that the energy that must be supplied to the machine's generator comes from a series of burners built into the device. 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.
COP_{Rated}	[-]	Machine's rated Coefficient of Performance.
$f_{DesignEnergyInput}$	[0..1]	Fraction of design energy input currently required by the machine.
$f_{DesignLoad}$	[0..1]	Fraction of rated load currently being met by the machine.
$\dot{Q}_{df}$	[kJ/hr]	Energy that must be supplied through direct firing.
$T_{chw,out}$	[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 a 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 gas (at higher pressure) before being passed to the condenser. Both the work of increasing the refrigerant pressure and the work of pumping the refrigerant around the

loop is performed by the compressor. In a "single effect" absorption machine, the vaporous refrigerant (typically water) returning from the evaporator is absorbed in a medium (often aqueous ammonia or lithium bromide) where it 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 energy is added by a combustion process 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.

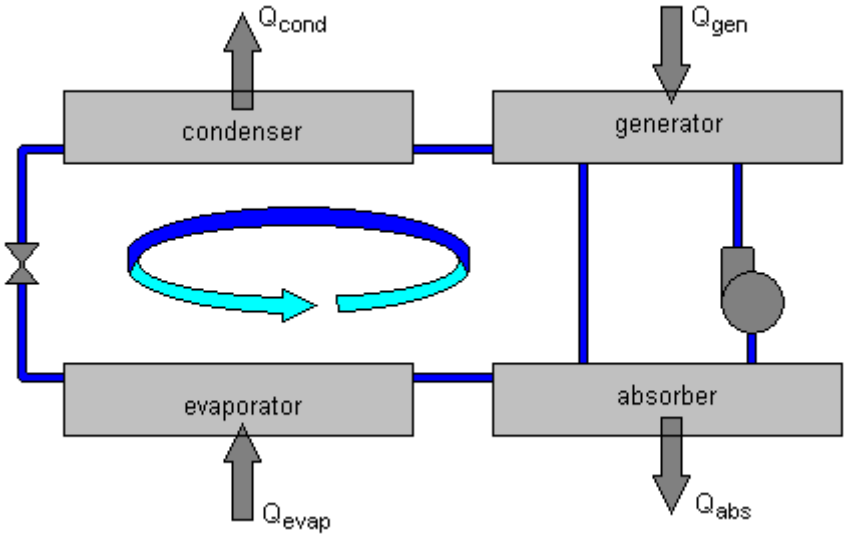


Figure 1: Single-Effect Absorption Chiller Device Schematic

The benefit of an absorption refrigerant cycles is that the energy required to pump the liquid (refrigerant in solution) 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 using a heat source instead of electricity. This fact makes absorption chillers especially valuable in cogeneration systems where waste heat from steam and other processes is abundant.

Type681 uses a catalog data lookup approach to predict the performance of a single effect, direct fired absorption chiller. In this design, the heat energy required to desorb the refrigerant is provided by a combustion process. Type681 is not capacity limited by the amount of energy available through the direct firing process because such machines are designed with integrated burners that are sized to be able to provide the appropriate amount of energy to the generator. 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, Type681 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.

Type681 requires a single data file that is specified in the standard TRNSYS data format. Since an example data file is included with this component, every effort should be made to preserve the syntactical format of the data. The example file is located in: \Catalog_Data\ABSCHLs\Single-Effect\Direct-Fired\Sample\S1.dat. The file contains values of normalized fraction of design energy input for various values of fraction of design load (dimensionless), chilled water set point (ºC) and entering cooling water temperature (ºC).

Upon determining that the absorption chiller is ON based on the value of the control signal, Type681 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 681.1

$$\dot{Q}_{remove} = \dot{m}_{chw} Cp_{chw} \left(T_{chw,in} - T_{chw,set} \right) \quad \text{(Eq. 681.1)}$$

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.

$$f_{DesignLoad} = \frac{\dot{Q}_{remove}}{Capacity_{Rated}} \quad \text{(Eq. 681.2)}$$

Type681 then calls the TRNSYS Dynamic Data subroutine with the above calculated fraction of design load, the chilled water set point temperature and the entering cooling water temperature. Dynamic Data returns the machine's fraction of required design energy input. The design energy input is the amount of energy that must be provided to the absorption chiller in order to chill the fluid stream under rated conditions. When operating under part load, some fraction of the design energy input must be provided and it is this fraction that Dynamic Data returns. The energy delivered to the chiller by direct firing is then calculated using equation 681.3

$$\dot{Q}_{df} = \frac{Capacity_{Rated}}{COP_{Rated}} f_{DesignEnergyInput} \quad \text{(Eq. 681.3)}$$

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

$$T_{chw,out} = T_{chw,in} - \frac{MIN\left(\dot{Q}_{remove}, Capacity\right)}{\dot{m}_{chw} Cp_{chw}} \quad \text{(Eq. 681.4)}$$

In order for energy to balance in the device, the energy rejection to the cooling water stream must be equal to the energy added by direct firing as shown in equation is given by 681.5

$$\dot{Q}_{cw} = \dot{Q}_{chw} + \dot{Q}_{df} + \dot{Q}_{aux} \quad \text{(Eq. 681.5)}$$

The term Q_{aux} accounts for the energy drawn 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. Type681 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 681.6.

$$T_{cw,out} = T_{cw,in} + \frac{\dot{Q}_{cw}}{\dot{m}_{cw} Cp_{cw}} \quad \text{(Eq. 678.6)}$$

The device COP is defined as shown in equation 681.7

$$COP = \frac{\dot{Q}_{chw}}{\dot{Q}_{aux} + \dot{Q}_{df}} \quad \text{(Eq. 681.7)}$$