TYPE 678: DOUBLE-EFFECT DIRECT-FIRED ABSORPTION CHILLER

General Description

Type678 uses a normalized catalog data lookup approach to model a double-effect direct fired absorption chiller. "Direct Fired" indicates that the energy that must be supplied to the machine's generator comes from a burner (natural gas or other combustible fuel) built into the machine. 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 gas 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 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 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). In a double effect machine, two individual absorption cycles are used; a high temperature absorption machine rejects energy from its condenser to the generator of a low temperature machine. A double effect absorption cycle is shown schematically in Figure 1.

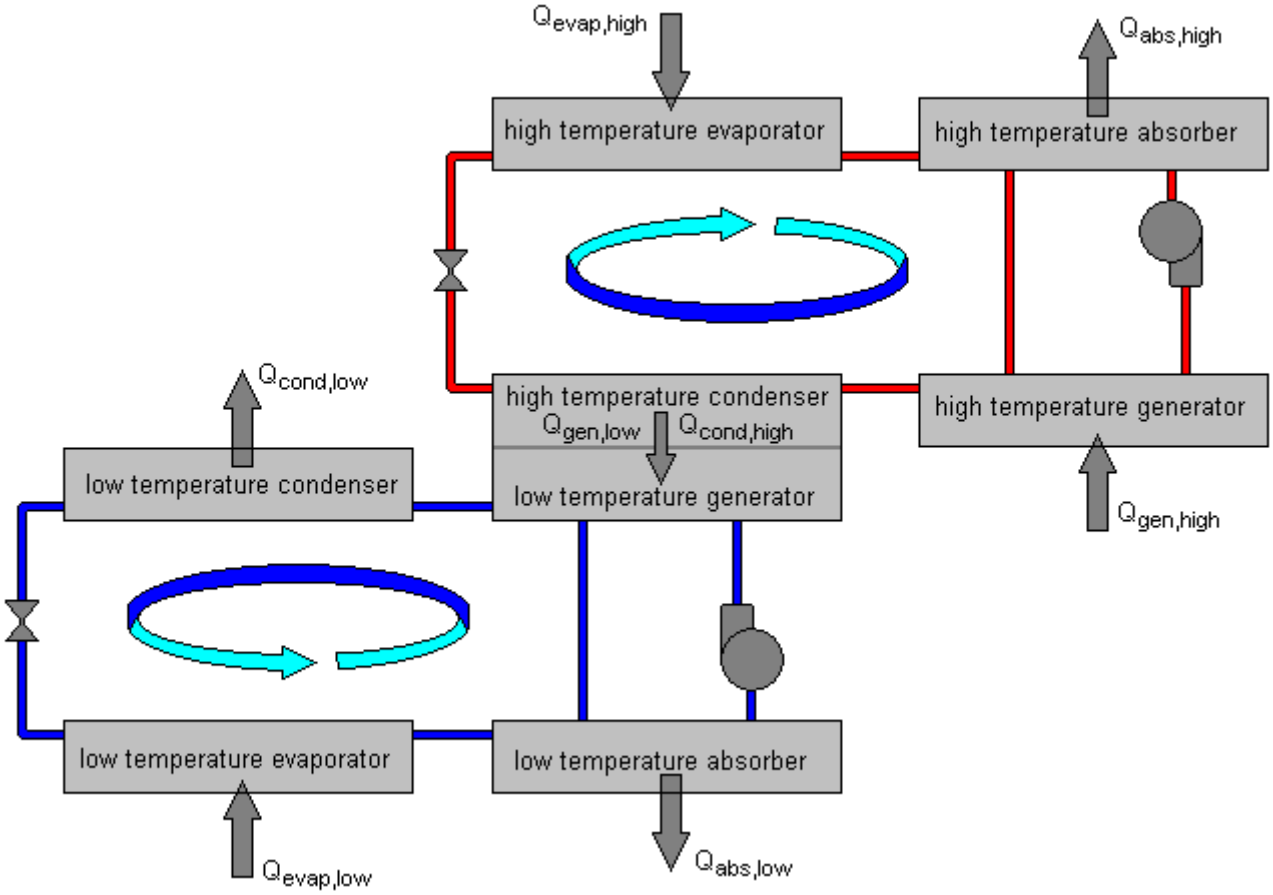


Figure 1: Double-Effect Absorption Chiller Device Schematic

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.

Type678 uses a catalog data lookup approach to predict the performance of a double effect, direct fired absorption chiller. In this design, the heat energy required to desorb the refrigerant is provided by a combustion process. Type678 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, Type678 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.

Type678 requires two data files, both 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\Double-Effect\Direct-Fired\Sample\S2.dat) contains values of normalized fraction of full load capacity for various values of chilled water set point and entering cooling water temperature (each specified in ºC). The second file (example located in: \Catalog_Data\ABSCHLs\Double-Effect\Direct-Fired\Sample\S3.dat) provides values of fraction of design energy input for various values of entering cooling water temperature (ºC) and fraction of design load at current conditions. In essence the first data file provides the user with the fraction of full load capacity available given the conditions of the cooling water stream and the desired set point. The second file provides the user with the fraction of the rated input energy that will be required in order to carry out the process. The example files are duplicated at the end of this document for reference.

Upon determining that the absorption chiller is ON based on the value of the control signal, Type678 first calls the TRNSYS Dynamic Data subroutine with the user specified chilled fluid set point temperature and entering cooling water temperature. Dynamic Data reads the data file and returns the fraction of the machine's rated capacity that is available given those conditions. The capacity of the machine at any given time is then given by equation 678.1.

$$Capacity = f_{FullLoadCapacity} Capacity_{Rated} \quad \text{(Eq. 678.1)}$$

The total amount of energy that must be removed from the chilled fluid stream by the machine can then be calculated using equation 678.2

$$\dot{Q}_{remove} = \dot{m}_{chw} Cp_{chw} \left(T_{chw,in} - T_{chw,set} \right) \quad \text{(Eq. 678.2)}$$

In order to read the second data file, the fraction of design load must be known. The fraction of design load is simply the amount of energy that must be removed from the chilled fluid stream divided by the machine's rated capacity (in other words the maximum amount of energy that the machine is capable of removing from the chilled fluid stream.) It is calculated using equation 678.3.

$$f_{DesignLoad} = \frac{\dot{Q}_{remove}}{Capacity_{Rated}} \quad \text{(Eq. 678.3)}$$

On the basis of the design load fraction and knowing the cooling fluid inlet temperature, Dynamic Data is queried a second time, this time returning the machine's fraction of 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 678.4

$$\dot{Q}_{df} = \frac{Capacity_{Rated}}{COP_{Rated}} f_{DesignEnergyInput} \quad \text{(Eq. 678.4)}$$

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

$$T_{chw,out} = T_{chw,in} - \frac{MIN\left(\dot{Q}_{remove}, Capacity\right)}{\dot{m}_{chw} Cp_{chw}} \quad \text{(Eq. 678.5)}$$

In order for energy to balance in the device, the energy rejection to the cooling water stream is equal to the energy added by direct firing. The energy rejection to the cooling water stream is given by 678.6

$$\dot{Q}_{cw} = \dot{Q}_{chw} + \dot{Q}_{df} + \dot{Q}_{aux} \quad \text{(Eq. 678.6)}$$

The term Q_{aux} accounts for the additional 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. Type678 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 678.7.

$$T_{cw,out} = T_{cw,in} + \frac{\dot{Q}_{cw}}{\dot{m}_{cw} Cp_{cw}} \quad \text{(Eq. 678.7)}$$

The device COP is defined as shown in equation 678.8

$$COP = \frac{\dot{Q}_{chw}}{\dot{Q}_{aux} + \dot{Q}_{df}} \quad \text{(Eq. 678.8)}$$

The following tables contain example data from the three files required by Type678.

Sample S2.dat

```
4.4444  5.5556  6.6667  7.7778  8.8889             !Chilled Water Setpoint (C)
23.8889  26.6667  29.4444  32.2222  35.0000        !Entering Cooling Water Temperature (C)
1.12                                    !Fraction of Nominal Capacity at 4.4444 and 23.8889
1.00                                    !Fraction of Nominal Capacity at 4.4444 and 26.6667
0.84                                    !Fraction of Nominal Capacity at 4.4444 and 29.4444
0.66                                    !Fraction of Nominal Capacity at 4.4444 and 32.2222
0.48                                    !Fraction of Nominal Capacity at 4.4444 and 35.0000
1.12                                    !Fraction of Nominal Capacity at 5.5556 and 23.8889
1.08                                    !Fraction of Nominal Capacity at 5.5556 and 26.6667
0.92                                    !Fraction of Nominal Capacity at 5.5556 and 29.4444
0.74                                    !Fraction of Nominal Capacity at 5.5556 and 32.2222
0.56                                    !Fraction of Nominal Capacity at 5.5556 and 35.0000
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1.12                                    !Fraction of Nominal Capacity at 6.6667 and 23.8889
1.12                                    !Fraction of Nominal Capacity at 6.6667 and 26.6667
1.00                                    !Fraction of Nominal Capacity at 6.6667 and 29.4444
0.83                                    !Fraction of Nominal Capacity at 6.6667 and 32.2222
0.65                                    !Fraction of Nominal Capacity at 6.6667 and 35.0000
1.12                                    !Fraction of Nominal Capacity at 7.7778 and 23.8889
1.12                                    !Fraction of Nominal Capacity at 7.7778 and 26.6667
1.06                                    !Fraction of Nominal Capacity at 7.7778 and 29.4444
0.90                                    !Fraction of Nominal Capacity at 7.7778 and 32.2222
0.73                                    !Fraction of Nominal Capacity at 7.7778 and 35.0000
1.12                                    !Fraction of Nominal Capacity at 8.8889 and 23.8889
1.12                                    !Fraction of Nominal Capacity at 8.8889 and 26.6667
1.12                                    !Fraction of Nominal Capacity at 8.8889 and 29.4444
0.97                                    !Fraction of Nominal Capacity at 8.8889 and 32.2222
0.80                                    !Fraction of Nominal Capacity at 8.8889 and 35.0000
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Sample S3.dat

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12.7778  18.3333  23.8889  29.4444                    !Entering Cooling Water Temperatures (C)
0.0 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00 !Fraction of Design Load at Current Conditions (-)
0.00                            !Fraction of Design Energy Input at 12.778 & 0.0 Fraction of Design Load
0.08                            !Fraction of Design Energy Input at 12.778 & 0.1 Fraction of Design Load
0.14                            !Fraction of Design Energy Input at 12.778 & 0.2 Fraction of Design Load
0.20                            !Fraction of Design Energy Input at 12.778 & 0.3 Fraction of Design Load
0.26                            !Fraction of Design Energy Input at 12.778 & 0.4 Fraction of Design Load
0.32                            !Fraction of Design Energy Input at 12.778 & 0.5 Fraction of Design Load
0.39                            !Fraction of Design Energy Input at 12.778 & 0.6 Fraction of Design Load
0.45                            !Fraction of Design Energy Input at 12.778 & 0.7 Fraction of Design Load
0.51                            !Fraction of Design Energy Input at 12.778 & 0.8 Fraction of Design Load
0.57                            !Fraction of Design Energy Input at 12.778 & 0.9 Fraction of Design Load
0.63                            !Fraction of Design Energy Input at 12.778 & 1.0 Fraction of Design Load
0.00                            !Fraction of Design Energy Input at 18.333 & 0.0 Fraction of Design Load
0.10                            !Fraction of Design Energy Input at 18.333 & 0.1 Fraction of Design Load
0.16                            !Fraction of Design Energy Input at 18.333 & 0.2 Fraction of Design Load
0.23                            !Fraction of Design Energy Input at 18.333 & 0.3 Fraction of Design Load
0.30                            !Fraction of Design Energy Input at 18.333 & 0.4 Fraction of Design Load
0.38                            !Fraction of Design Energy Input at 18.333 & 0.5 Fraction of Design Load
0.45                            !Fraction of Design Energy Input at 18.333 & 0.6 Fraction of Design Load
0.53                            !Fraction of Design Energy Input at 18.333 & 0.7 Fraction of Design Load
0.62                            !Fraction of Design Energy Input at 18.333 & 0.8 Fraction of Design Load
0.71                            !Fraction of Design Energy Input at 18.333 & 0.9 Fraction of Design Load
0.80                            !Fraction of Design Energy Input at 18.333 & 1.0 Fraction of Design Load
0.00                            !Fraction of Design Energy Input at 23.889 & 0.0 Fraction of Design Load
0.14                            !Fraction of Design Energy Input at 23.889 & 0.1 Fraction of Design Load
0.20                            !Fraction of Design Energy Input at 23.889 & 0.2 Fraction of Design Load
0.26                            !Fraction of Design Energy Input at 23.889 & 0.3 Fraction of Design Load
0.34                            !Fraction of Design Energy Input at 23.889 & 0.4 Fraction of Design Load
0.42                            !Fraction of Design Energy Input at 23.889 & 0.5 Fraction of Design Load
0.50                            !Fraction of Design Energy Input at 23.889 & 0.6 Fraction of Design Load
0.59                            !Fraction of Design Energy Input at 23.889 & 0.7 Fraction of Design Load
0.68                            !Fraction of Design Energy Input at 23.889 & 0.8 Fraction of Design Load
0.78                            !Fraction of Design Energy Input at 23.889 & 0.9 Fraction of Design Load
0.90                            !Fraction of Design Energy Input at 23.889 & 1.0 Fraction of Design Load
0.00                            !Fraction of Design Energy Input at 29.444 & 0.0 Fraction of Design Load
0.16                            !Fraction of Design Energy Input at 29.444 & 0.1 Fraction of Design Load
0.23                            !Fraction of Design Energy Input at 29.444 & 0.2 Fraction of Design Load
0.32                            !Fraction of Design Energy Input at 29.444 & 0.3 Fraction of Design Load
0.40                            !Fraction of Design Energy Input at 29.444 & 0.4 Fraction of Design Load
0.48                            !Fraction of Design Energy Input at 29.444 & 0.5 Fraction of Design Load
0.56                            !Fraction of Design Energy Input at 29.444 & 0.6 Fraction of Design Load
0.64                            !Fraction of Design Energy Input at 29.444 & 0.7 Fraction of Design Load
0.75                            !Fraction of Design Energy Input at 29.444 & 0.8 Fraction of Design Load
0.86                            !Fraction of Design Energy Input at 29.444 & 0.9 Fraction of Design Load
1.00                            !Fraction of Design Energy Input at 29.444 & 1.0 Fraction of Design Load
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