4.3. Type 927: Water – Water Heat Pump

This component models a single-stage heat pump. The heat pump conditions a one liquid stream by rejecting energy to (cooling mode) or absorbing energy from (heating mode) a second. This model is based on user-supplied data files containing catalog data for the capacity and power draw, based on the entering load and source temperatures. Type927 operates in temperature level control much like an actual heat pump would; when the user defined control signal indicates that the unit should be ON in either heating or cooling mode, it operates at its capacity level until the control signal values changes.

4.3.1. Nomenclature

COP	[-]	The heat pump coefficient of performance in either heating or cooling mode.
$Cap_{heating}$	[kJ/hr]	Heat pump heating capacity at current conditions.
$Cap_{cooling}$	[kJ/hr]	Heat pump cooling capacity at current conditions.
$\dot{P}_{heating}$	[kJ/hr]	Power drawn by the heat pump in heating mode.
$\dot{P}_{cooling}$	[kJ/hr]	Power drawn by the heat pump in cooling mode.
$\dot{Q}_{absorbed}$	[kJ/hr]	Energy absorbed by the heat pump in heating mode.
$\dot{Q}_{rejected}$	[kJ/hr]	Energy rejected by the heat pump in cooling mode
$T_{source,in}$	[ºC]	Temperature of liquid entering the source side of the heat pump.
$T_{source,out}$	[ºC]	Temperature of liquid exiting the source side of the heat pump.
$T_{load,in}$	[ºC]	Temperature of liquid entering the load side of the heat pump.
$T_{load,out}$	[ºC]	Temperature of liquid exiting the load side of the heat pump.
$\dot{m}_{source}$	[kg/hr]	Mass flow rate of the liquid on the source side of the heat pump.
Cp_{source}	[kJ/kg.K]	Specific heat of the liquid on the source side of the heat pump.
$\dot{m}_{load}$	[kg/hr]	Mass flow rate of the liquid on the load side of the heat pump.

Cp_{load}	[kJ/kg.K]	Specific heat of the liquid on the load side of the heat pump.

4.3.2. Mathematical Description

A heat pump is a device that transfers energy from a low temperature source to a higher temperature sink. It differs from a pure refrigeration cycle in that the end result of the application could be either to heat or cool depending upon the direction that the refrigerant is currently flowing through the system [1]. **Error! Reference source not found.** shows a schematic diagram of a heat pump system.

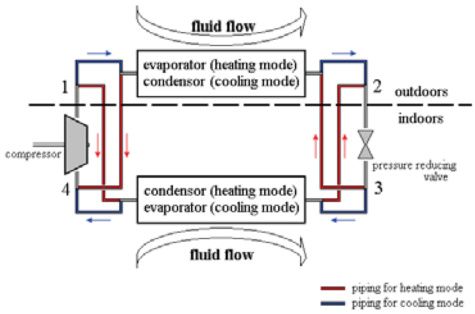

Figure 1: Heat Pump Schematic

The numbered points on the diagram correspond to the refrigerant states shown on the psychrometric chart in **Error! Reference source not found.**.

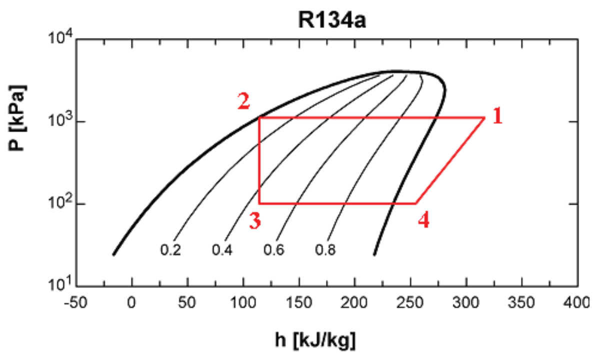

Figure 2: A Generic Heat Pump Cycle

Type927 is not a first principals model but relies instead upon catalog data readily available from heat pump manufacturers. At the heart of the component are two data files: a file containing cooling performance data, and a file containing heating performance data. Both data files provide capacity and power draw of the heat pump (whether in heating or cooling mode) as functions of entering source fluid temperature and entering load fluid temperature

Both data files use the standard format for TRNSYS data files as outlined in section 8.4.4.4 of the 08 Programmer’s Guide in the TRNSYS documentation set. As such, Type927 is able to interpolate data within the range of input values specified in the data files. It is, however, not able to extrapolate beyond the data range and will print a warning in the TRNSYS list file and simulation log if conditions fall outside the data range.

4.3.2.1. Cooling Performance Data

An example cooling performance data file is provided for use with Type927. The file samp_c.dat can be found in ..\Trnsys17\Tess Models\SampleCatalogData\Water-to-WaterHeatPump\. Users creating their own performance data must adhere closely to the syntax of the sample file. The values of entering load temperature must all appear (in ºC) separated by spaces on the first line of the data file. The load temperature is typically the temperature of liquid returning to the heat pump from the building spaces; in cooling mode, the liquid stream on the load side of the heat pump will exit the heat pump colder than it entered. The values of entering source temperature must all appear on the second line of the data file (again in ºC and again space delimited). In a typical ground source heat pump application, the source side of the heat pump is the bore field side. Users may specify more or fewer values of each of these two independent variables than are shown in the sample file but must also remember to modify the corresponding PARAMETER in the TRNSYS input file. The values of both cooling performance measures (capacity in kW and power drawn in kW) and must then appear, each pair on its own line.

4.3.2.2. Heating Performance Data

The specification of heating performance data is much the same as for cooling performance data. Two measures of heating performance must be provided in the heating performance data file. These are: total heating capacity (in kW), and power consumed (also in kW). Type927 linearly interpolates between heating performance measures based on the current values of the entering source fluid temperature (in ºC) and the entering load fluid temperature (in ºC). An example heating performance data file is provided for use with Type927. The file samp_h.dat can be found in ..\Trnsys17\Tess Models\SampleCatalogData\Water-to-WaterHeatPump\. Users creating their own performance data must again adhere closely to the syntax of the sample file. The values of entering load temperature must all appear (in ºC) separated by spaces on the first line of the data file. The load temperature is typically the temperature of liquid returning to the heat pump from the building spaces; in heating mode, the liquid stream on the load side of the heat pump will exit the heat pump hotter than it entered. The values of entering source temperature must all appear on the second line of the data file (again in ºC and again space delimited). In a typical ground source heat pump application, the source side of the heat pump is the bore field side. Users may specify more or fewer values of each of these two independent variables than are shown in the sample file but must also remember to modify the corresponding PARAMETER in the TRNSYS input file. The values of both cooling performance measures (capacity in kW and power drawn in kW) and must then appear, each pair on its own line.

4.3.2.3. Heat Pump Performance

The Type927 heat pump is equipped with two control signals, one for heating and one for cooling. The model does not generate a warning if the user sets both control signals to 1. However, heating mode takes precedence over cooling mode. If the heating and cooling control signals are both ON, the model will ignore the cooling control signal and will operate in heating mode.

If the heat pump is determined to be ON in heating mode (INPUT 6 set to 1), Type927 calls the TRNSYS Data subroutine with the entering source and load fluid. The Data routine accesses the heating performance data file (specified by the user as a logical unit number in the input file) and returns the machine’s heating capacity and power draw. The heat pump’s COP in heating is given by equation 927.1

$$COP = \frac{Cap_{heating}}{\dot{P}_{heating}} \quad \text{(Eq. 927.1)}$$

The amount of energy absorbed from the source fluid stream in heating is given by equation 927.2

$$\dot{Q}_{absorbed} = Cap_{heating} - \dot{P}_{heating} \quad \text{(Eq. 927.2)}$$

The outlet temperatures of the two liquid streams can then be calculated using equations 927.3 and 927.4.

$$T_{source,out} = T_{source,in} - \frac{\dot{Q}_{absorbed}}{\dot{m}_{source} Cp_{source}} \quad \text{(Eq. 927.3)}$$

$$T_{load,out} = T_{load,in} - \frac{Cap_{heating}}{\dot{m}_{load} Cp_{load}} \quad \text{(Eq. 927.4)}$$

If the heat pump is determined to be ON in cooling mode (INPUT 5 set to 1), Type927 operates in much the same fashion as in heating mode. It calls the TRNSYS Data subroutine with the entering source and load fluid. The Data routine now accesses the cooling performance data file (specified by the user as a logical unit number in the input file) and returns the machine’s cooling capacity and power draw. The heat pump’s COP in cooling is given by equation 927.5

$$COP = \frac{Cap_{cooling}}{\dot{P}_{cooling}} \quad \text{(Eq. 927.5)}$$

The amount of energy rejected by the source fluid stream in cooling is given by equation 927.6.

$$\dot{Q}_{rejected} = Cap_{cooling} + \dot{P}_{cooling} \quad \text{(Eq. 927.6)}$$

The outlet temperatures of the two liquid streams can then be calculated using equations 927.7 and 927.8.

$$T_{source,out} = T_{source,in} + \frac{\dot{Q}_{rejected}}{\dot{m}_{source} Cp_{source}} \quad \text{(Eq. 927.7)}$$

$$T_{load,out} = T_{load,in} + \frac{Cap_{cooling}}{\dot{m}_{load} Cp_{load}} \quad \text{(Eq. 927.8)}$$

4.3.3. References

[1] Mitchell, J.W. and J.E. Braun, Design Analysis, and Control of Space Conditioning Equipment and Systems, Solar Energy Laboratory, University of Wisconsin – Madison. 1997