TECHNICAL DESCRIPTION OF THE SOFTWARE

The software, hereto referred to as IMST-ART, is to have the capability of predicting system performance assuming different components for a vapour compression cycle.

This software can work under SI or IP units system.

IMST-ART© has the features described below. A printable online help in pdf form is included with the program and can be accessed by pressing F1 key.

Working Cycle

This program calculates the operating point and performance of a single stage sub-critical vapour compression cycle composed of a compressor, an evaporator, a condenser, a thermostatic expansion valve, and suction, discharge and liquid pipes. The working fluid used in the cycle can be any of the refrigerants included in NIST Standard Reference Database 23 Version 7.0 **[1]** (commonly known as REFPROP Database). The heat source/heat sink fluids can be dry/humid air, water or any of the secondary refrigerants (brines) included in the book edited by IIR "Thermophysical Properties of Liquid Secondary Refrigerants" **[2].** Properties of the humid air are calculated from the equations provided by ASHRAE **[3]**

Compressor input data include the compressor nominal displacement and speed, oil volume, oil circulation rate and the corresponding heat losses to the ambient as a percentage of the power input. Several modelling options for the compressor can be chosen by the user. These modelling options are:

- <u>Constant efficiencies</u>: User can give as input data either the volumetric efficiency and compressor efficiency, or the performance of the compressor in terms of cooling capacity and power input at ARI and ASERCOM standard points or at user defined conditions. Volumetric efficiency and compressor efficiency are then assumed constant.
- <u>Default efficiencies</u>: User can choose any of the five predefined compressors types (scroll-hermetic, reciprocating-hermetic, reciprocating-semi hermetic, screw or rotary). Predefined typical fitted curves of efficiency and volumetric efficiency for each compressor type are used in the simulation.
- <u>Single point adjustment</u>: User can choose the compressor type and then to specify a real performance point of the compressor in either of the following options: known compressor efficiency and volumetric efficiency at a given pressure ratio; known point of the compressor catalogue data; or known performance of the compressor at ARI and ASERCOM standard points or at user defined conditions. The predefined compressor curves for volumetric and compressor efficiency, depending on the chosen compressor type, are then shifted to pass through the specified performance point.
- <u>Detailed efficiencies</u>: User can choose to introduce the real compressor efficiency and volumetric efficiency by three different ways: efficiency vs. pressure ratio single points table or polynomial, or alternatively by giving the coefficients of the ARI standard polynomial (ARI 544-99) **[4]**, for the compressor mass flow rate and power input.

The specified data can be saved in an internal compressor database in order to be able to reload it when required.

Evaporator and condenser input data include the heat source/sink fluid, the inlet temperature and outlet temperature or inlet flow conditions, inlet pressure and inlet humidity or wet bulb temperature (if applicable). HE simulation can be performed under different levels of modelling depending on the User available data and the required accuracy. These different modelling levels are:

- Constant Evap/Cond Temperature: This model merely sets the corresponding saturation temperature. An additional option is to set the estimated pressure drop (given in equivalent saturation temperature units) to calculate its effect in the Cycle performance. User has to use this type of HE if he wants to evaluate theoretical performance or for doing preliminary design.
- Total Area: This is a global approach modelling using the effectiveness-NTU formulae. User provides heat transfer area of the HE, estimated pressure drop, and the overall heat transfer coefficient (HTC). This overall HTC can be given as a constant value or as a function of heat flux or secondary mass flow rate.
- Coil: This is a detailed simulation of tubes and fins heat exchanger. User gives the general dimensions of the heat exchanger, the tube and fin data, the distributor data, the flow arrangement and chooses the heat transfer coefficient correlation and pressure drop correlation from an internal database. The heat exchanger is divided into a series of cells and mass, momentum and energy conservation equations in their one-dimensional form are solved for every cell. The humid air combined heat and mass transfer (dehumidification process) is also solved in each air cell. The calculation assumes the same heat transfer and pressure drop characteristics for every refrigerant circuit.
- Plates: This heat exchanger model is used for the detailed simulation of single pass Plate Heat Exchangers working under cocurrent or countercurrent conditions. The input data to the model are the flow arrangement, geometric data for the plates, the corrugation, the distributor orifice, if it is the case, and the ports. Then the user can select among a series of built in HTC and pressure drop correlations. The heat exchanger is divided in cells and the equations of mass, momentum and energy conservation equations in their one-dimensional form are solved for every cell. The calculation assumes 1D flow through the channel and identical heat transfer and pressure drop performance for every refrigerant channel.

The user has the option of saving and reading heat exchanger data.

There are three different expansion devices types available: Thermostatic expansion valve, capillary tube and short tube orifice.

The thermostatic expansion valve is simulated setting a constant superheat at the evaporator outlet. Therefore, only the introduction of the superheat is required as input data.

Capillary tubes can be of adiabatic or non adiabatic types. There are two models available to calculate adiabatic capillary tubes, ASHRAE Correlation and Two Phase Separated Flow, the first one is the empirical correlation recommended by ASHRAE **[5]** and the second is a one dimensional model of the capillary tube that solves the continuity, momentum and energy equation of the two phase flow through the capillary using a separated flow model.

Non adiabatic capillary tubes are calculated using the correlation provided by ASHRAE **[5]**.

Calculation of the refrigerant flow along the piping and accessories is optional in the program.

If this option is not activated, the User has to set the additional superheat from the evaporator outlet to the compressor inlet and the additional subcooling from the condenser outlet to the TXV inlet that would be produced by the suction and liquid lines. On the other hand, the compressor discharge line is assumed to generate null desuperheat. So no input data is required in this line.

If the User chooses the option of "piping calculation", the program calculates both heat transfer to the external environment and pressure drop of the refrigerant along the pipes. Data needed for pipes are: pipe material, external diameter, thickness, length of the pipe, inlet and outlet height, insulation material and thickness, type of external heat transfer, environment temperature, external air velocity (if required) and imposed extra superheat/desuperheat/subcooling (this last item depends on the pipe type). User has also the option to include the pressure drop through pipe accessories: globe or solenoid valves, angle valve, short radius elbow, long radius elbow, and sight glasses. The option to define new pipe and insulation materials and save them into the materials database is included.

There is the option to include the calculation of a suction-to-line heat exchanger and a four way valve in the accessories.

The calculation of the suction to line heat exchanger can be made by using the following modes:

- Simplified Calculation: User sets the additional subcooling introduced by this heat exchanger.
- Given UA: User gives the Overall Heat transfer coefficient times Area of the heat exchanger. A global approach modelling using the effectiveness-NTU formulae is used to calculate its performance.
- Detailed Calculation: User has to define the capacity of the HE under a given condition (defined by the HE catalogue).

The four ways valve can be simulated using two different models:

- Simplfied Calculation: The user has to set the superheat produced by this element. the corresponding Desuperheat at discharge line is calculated.
- Detailed Calculation: User has to provide the suction inlet diameter, nominal pressure drop, capacity at given conditions (ARI and ASERCOM standards points or User defined conditions) and optionally internal leakage and nominal superheat.

Charge of the system must be set in order to calculate the system. Two conditions can replace this data, to give a subcooling at condenser outlet or to define a liquid receiver at condenser outlet.

The program allows performing parametric studies with variation of any input data in order to analyse its effect on cycle and system performance. Plotting of the obtained results and printing versus the varied parameters is straightforward.

The output data offered by the program includes all the input data, the thermodynamic properties of the refrigerant at every point of the cycle, circulating mass flow rate, evolution of the refrigerant and heat source/sink fluid along the detailed HEX, cooling capacity, COP, pressure ratio, pressure drop in the heat exchanger, refrigerant charge, etc. Data is presented for each component in a set of formatted tables for each component of the cycle. Output data can also be shown in X-Y plots if user has made a parametric study choosing any variable as X data and Y data. Plotting capabilities of the program also include graphical representation of local variables inside the detailed heat exchangers like pressure, temperature, local heat transfer coefficient and more. Cut and paste of the output data is available as well as printing of the output data and plots.

HARD- AND SOFTWARE REQUIREMENTS

With regard to the system requirements for IMST-ART the following minimum can be recommended:

Hardware: Pentium based PC;

1 GB RAM-memory (total);

VGA colour monitor and a video card (resolution 1024 x 768, 256 colours);

MS-Windows compatible mouse;

Font size: 96 dpi (dots per inch);

Software: Windows Vista/7/8/10 or superior

References

[1] Mark O. McLinden et al."NIST standard Reference Database 23-NIST Reference Fluid Thermodynamic and Transport Properties--REFPROP"**,** 2002 *National Institute of Standards and Technology.*

[2] Ake Melinder, "Thermophysical properties of Liquid Secondary Refrigerants", 1997, *International Institute of Refrigeration.*

[3] ASHRAE, 2005, Chapter 6, Psychrometrics **.**"2005 ASHRAE Handbook Fundamentals", Atlanta, 2005

[4] _______, "Standard 540, Standard for positive displacement compressors and compressors units", 1999, *ARI (Air Conditioning and Refrigeration Institute)*

[5] ASHRAE, "ASHRAE Handbook, vol. Refrigeration", American Society of Heating, Refrigeration and Air Conditioning Engineers Inc., Atlanta, 2002.