T H E R M O P T I M ®

OFF-DESIGN OPERATION

PRACTICAL USE OF THE

REFRIGERATION MACHINE DRIVER

JAVA VERSION 1.7 OR 2.7

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CONTENTS

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1 Introduction

The purpose of this notice is to show you how to use of a driver for studying the off-design behavior of a refrigeration cycle with Thermoptim. You will find explanations on how are completed technological design and off-design studies in the Thermoptim portal[1].

We assume you already know well Thermoptim and its external class mechanism, and that you are acquainted with the role of this refrigeration cycle driver, whose construction is explained in another document[2].

2 Driver screen

The driver screen is shown in Figure 1.

It allows you to change the exchanger surfaces, the length of the liquid line, air temperature, rotation speed or displacement. It has options for the algorithm guidance.

By default, the rotation speed is calculated for the value of the displacement entered in the screen. If you select "Calculate Vs" the displacement is calculated for the value of the speed entered.

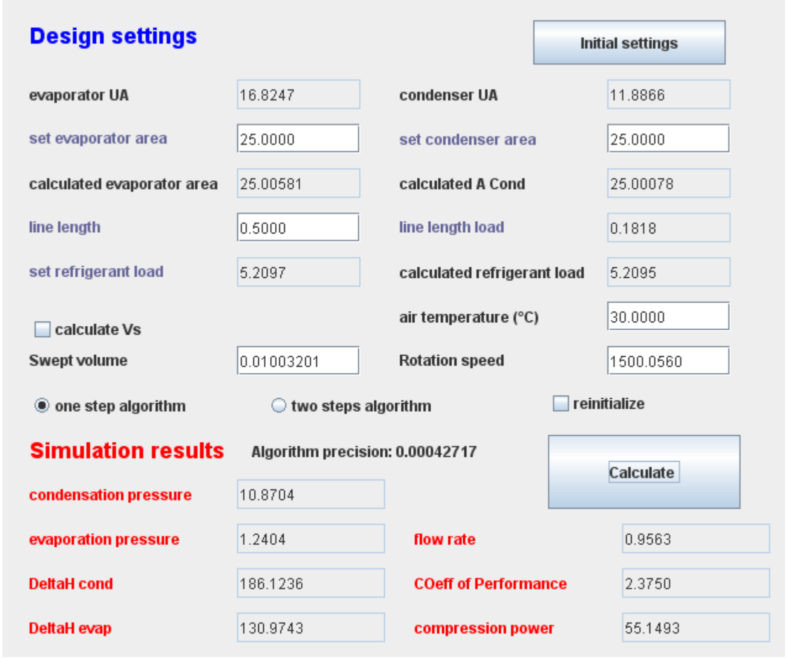

Figure 1: Driver screen

2. 1 Initial settings

Start by clicking "Initial settings" to make an initial technological design, in this case calculate the rotation speed or displacement of the compressor and the surfaces of the two exchangers corresponding to the project file setup, on the basis of the TechnoDesign parameter values which have been entered.

2. 2 Calculation of a new state

To calculate a new state, enter then a new value of the air temperature, not too far from the previous one, for instance 25 °C, and either click "Calculate" or preferably open the TechnoDesign screen from the simulator, then click "Calculate the driver". The second way is preferable because it allows you to track the convergence while keeping hands on Thermoptim to display intermediate values, modify the calculation of the driver, or stop the calculations.

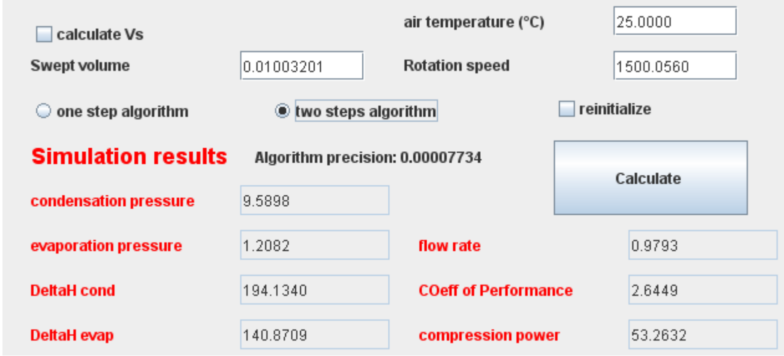

Figure 2: Driver screen

[1] http://www.thermoptim.org/sections/base-methodologique/dimensionnement/modeles-dimensionnement
[2] http://www.thermoptim.org/sections/logiciels/thermoptim/modelotheque/pilote-frigo-aux

The results are displayed on the driver screen once the convergence is obtained. If the new value you enter is very different from that of design, Thermoptim calculation errors can be generated with messages. You may even have to stop Thermoptim and restart it if the calculations go wrong. If necessary then, enter a new value closer to the initial one.

Figure 2 shows the simulation results obtained when convergence is obtained. Indeed this result was obtained after clicking several times "Calculate the driver" in order to make sure that the calculated evaporator and condenser areas where equal to those set, as the algorithm did not directly find the appropriate solution.

This driver allows you to choose between two algorithms, which are complementary: the “one step algorithm” is generally efficient to find an approximate solution of the new state, while the “two steps algorithm” will be more accurate once the first convergence is obtained.

2. 3 Backup of the new state in a separate project file

Once you have obtained a satisfying new state, it is recommended to save the project file before going further by entering a new value of the air temperature and using the driver to calculate the corresponding solution. You end up with a set of project files corresponding to the same design values and various operating conditions.

3 Post-processing of calculated project files

3.1 Loading the project flies in the Excel macro

The Excel macro[3] for post-processing Thermoptim files (Figure 3) allows you to load these project files into the spreadsheet, and then extract the values you are interested in from the cells of the different files.

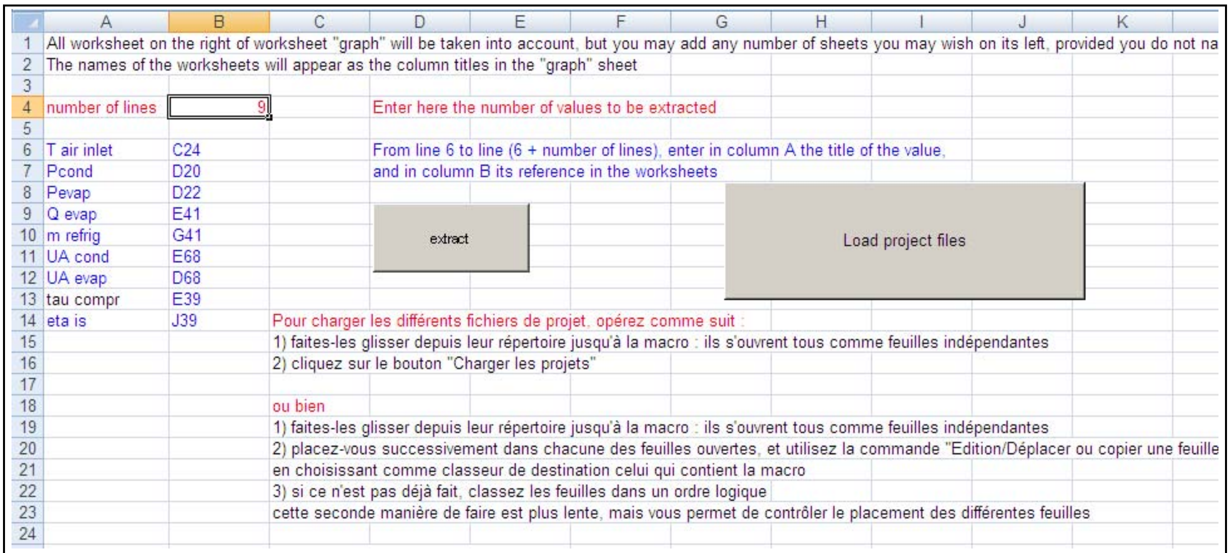

Figure 3: “macro” worksheet

To do this, proceed as follows:

1) Open the file explorer in your operating system (Windows in this example) and place the window just above the MacroPostProcessing.xls spreadsheet.
2) Select the files you want to process;
3) Drag them to the MacroPostProcessing.xls spreadsheet; They will each open as separate worksheets;
4) In each file, click on Edit/Move or copy a worksheet" and choose MacroPostProcessing.xls as the destination spreadsheet. Make sure you place them to the right of the worksheet called “graph”.
5) Arrange the worksheets in a logical order, if necessary.

[3] http://www.thermoptim.org/sections/logiciels/thermoptim/ressources/macro-excel-post

You can also replace steps 4 and 5, which can be time-consuming when there are a lot of worksheets to load, by clicking on the button “load the projects”, which will automatically load the projects. However, you may have to change manually the order in which the worksheets are arranged.

The project files thus automatically appear as worksheets in the spreadsheet, identified by their name without the extension. Obviously, you should first delete any worksheets relating to another project.

3.2 Defining the values to be extracted and running the macro

To extract the desired information:
1) In column A, starting at line 6, enter the labels you want included in the post-processing worksheet “graph”;
2) In column B, enter the cell reference in the project worksheets;
3) When you have finished, enter the number of values to be extracted in cell B4 (outlined);
4) Click on the button "extract".

In the example above, we wanted to extract the air inlet temperature, the condensation and evaporation pressures, the heat provided to the evaporator, the refrigerant flow rate, the condenser and evaporator UAs, the compressor work and isentropic efficiency, the corresponding cell numbers being entered in column B. As there are 9 values to be extracted, we enter 9 in cell B4.

Once the values to be extracted are selected, run the macro by clicking on the "extract" button. The macro runs through all the worksheets located to the right of the worksheet “graph” and copies the values of the selected cells, building the table shown in the upper part of figure 4.

4		refrigAux_dP_Displ_-10_	refrigAux_dP_Displ_0_2	refrigAux_dP_Displ_10_	refrigAux_dP_Displ_25	refrigAux_dP_Displ_30_2
5						
6	T air inlet	-10	0	10	25	30
7	Pcond	3	5	6	10	11
8	Pevap	1,05166935	1,09210631	1,13614156	1,20812861	1,24160476
9	Q evap	204	188	171	141	131
10	m refrig	1	1	1	1	1
11	UA cond	11	14	14	13	12
12	UA evap	17	17	17	17	16
13	tau compr	61	46,91	47,75	53,26	55,15
14	eta is	0,44961	0,71017	0,80397	0,8147	0,80592
15						
16						
17		-10	0	10	25	30
18	compressor work (kW)	61	47	48	53	55
19	cooling load (kW)	204	188	171	141	131
20	COP	3	4	4	3	2
21	m refrig	1,08274222	1,07064348	1,04369899	0,979224433	0,956356918
22	compr ratio	3,304925384	4,335520175	5,631129276	7,944149249	8,760199913

Figure 4: Values extracted by the macro

3.3 Processing the extracted values

You may then process these values as desired, calculating ratios (COP, compression ratio) or plotting them (Figure 5).

In this example the COP maximum value is explained by a sharp decrease of the isentropic efficiency when the compression ratio is below 4. Please refer to the Excel spreadsheet and files provided for further details.

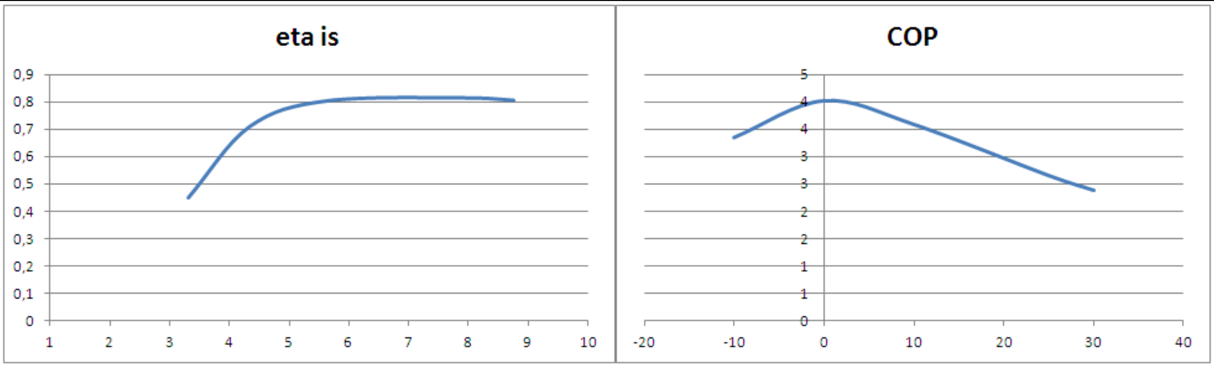

Figure 5: Isentropic efficiency function of the compression ratio and COP function of the air temperature

4 Remarks

Using a Thermoptim driver for studying the off-design behaviour of a system provides interesting insights but must be done cautiously because it may be difficult to find the solution of the set of equations representing the thermodynamic model.

It is recommended to calculate the various states by slowly varying the values of the variables, and to use the Excel macro to process the resulting files.

In addition, you must bear in mind all the model limitations, such as the cooling fluid minimum temperature (-15 °C for the 40% by volume propylene glycol) to make sure that the solution is within the boundaries.

5 Steam power plant off-design behaviour

A set of files allowing you to study the off-design behaviour of a simplified steam power plant model is provided in addition to that of the refrigeration machine. Note however that this simplified model is much less realistic than that of the refrigeration machine.