VCR: An interactive refrigeration system simulator

What VCR is

VCR stands for vapour compression refrigerator. The software calculates the behaviour of a refrigerated cold space, for example a cold-store, when it is subjected to variations in outdoor ambient conditions and the loading of (usually hot) food stuff and so on. The calculations VVCR does are based on scientifically based models of a system's components, including the cold space itself and right down to refrigerator pipe work. You design your system model using various input data screens and then run a simulation to see how much energy it uses and carbon it produces, amongst other things. The calculations are non-steady state and so time-dependent effects, such as the variation in outdoor dry bulb temperature, are accounted for. If you imagine a flight simulator software that allows you to design your own aircraft, well! VCR is a bit like that.

A schematic view of the basic system model is shown in Figure 1.

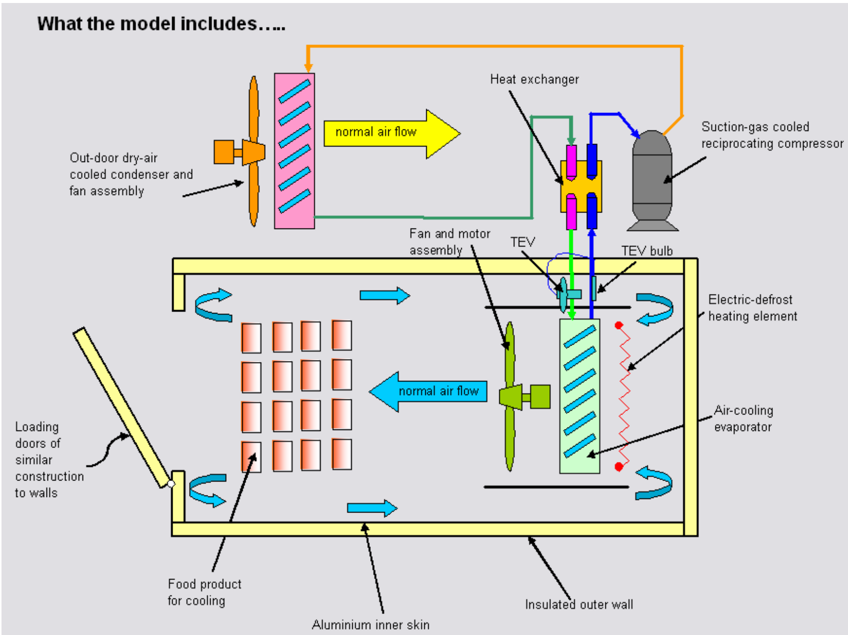


Figure 1: Schematic of refrigerated model cold space, from VCR-HELP

At the moment VCR is restricted to an air-air refrigerator powered by up to six staged hermetic or semi-hermetic reciprocating compressors and a thermostatic expansion valve. The model also assumes electrically heated evaporator defrost system and the compressor(s) is(are) controlled by thermostat.

Run-time screen functions

A Run-time screen, shown below in Figure 2, is provided through which all design screens and other functions are accessed. If necessary you can navigate through the system design using the *WIZARD* function or the *HELP* facility, both accessed by the click of a button in the toolbar in the Run-time screen. A typical *HELP* screen is shown in Figure 3.

Because VCR is a time-dependent simulator it is necessary for you to tell it between what times of the day you want to simulate your system's operation. These are known as 'model' start and end-times. These are set by you in the Run-time screen, which when the simulation is running, displays the current 'model-time'.

In addition and to setting both model start and end-times you will need to fix the model-time when the food stuff is loaded into the cold-space. This product loading time is just another of a number of selections you must make to run the simulation. The screens are easy to follow, but if you get stuck the *WIZARD* will help you through.

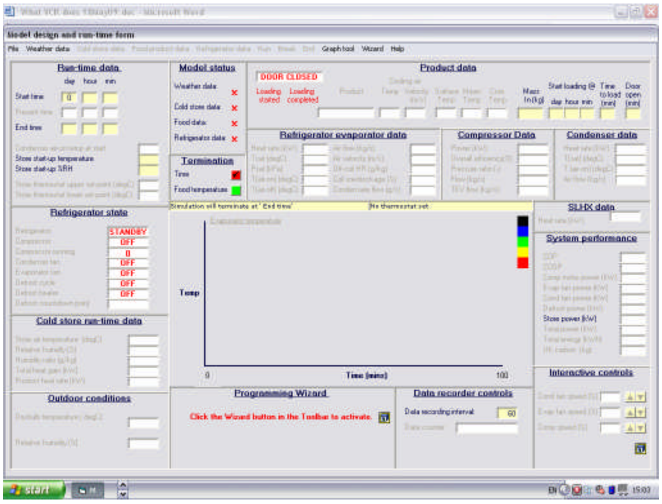


Figure 2: The run-time screen

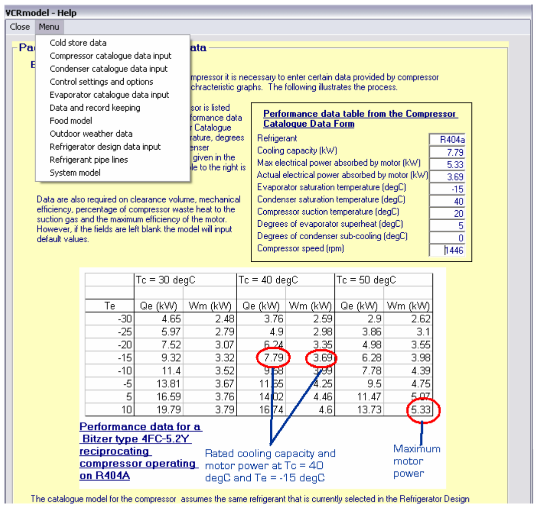


Figure 3: A typical HELP screen showing how to use the compressor catalogue data form

Design screen functions

Cold-store design: Easy to navigate design data input screens, exampled by those shown for the cold-store in Figure 4a and the Food-product in Figure 4b, are accessed through the Run-time screen for both the cold-store unit and refrigerator system. Both are provided with default data settings and guidance on the setting of design values through the *HELP* function. Data text boxes are also provided with 'hover' functions. When the cursor is placed over a data text box the range in which entry data should lie is automatically displayed for the users information. Also, in many cases, if inappropriate or out of range data are entered in text boxes then default values are automatically inserted by the software before the simulation can be run.

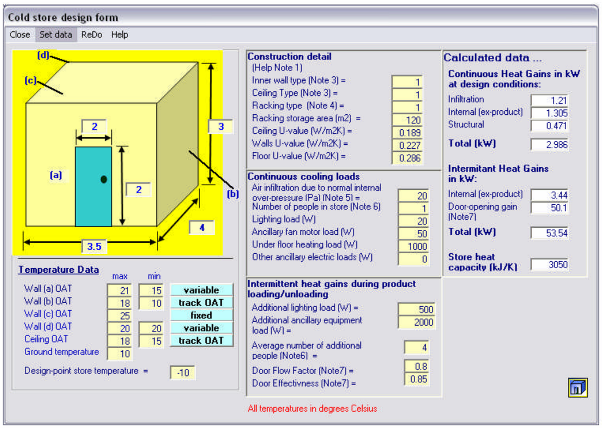


Figure 4(a): Cold store design screen

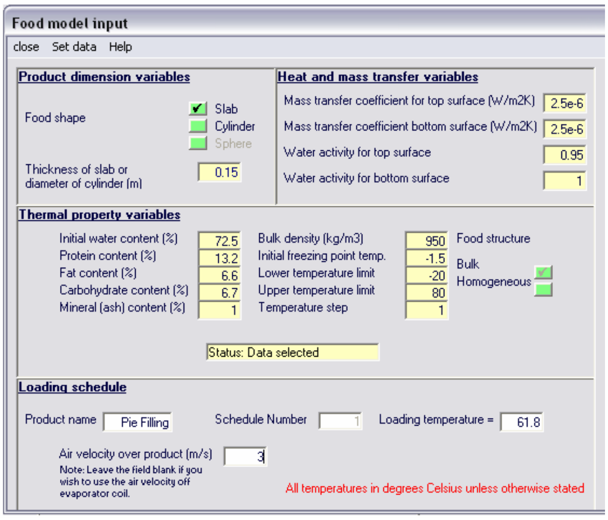


Figure 4(b): Food design screen

Refrigerator design: The refrigerator design screen, shown in Figure 5, allows users to specify design-point data either by default or individually or in any combinations, for the evaporator, condenser, compressor, fans and motors, thermostatic expansion valve, refrigerant pipelines and refrigerant fluid, as shown in Figure 6. If catalogue data are available for the compressor or evaporator or condenser (or for any combination of these) then special easy to follow data input screens are provided for each. These are accessed also by navigating through the toolbar, as shown in Figure 7. Figure 8 and 9 show the catalogue data entry screen for the compressor and evaporator.

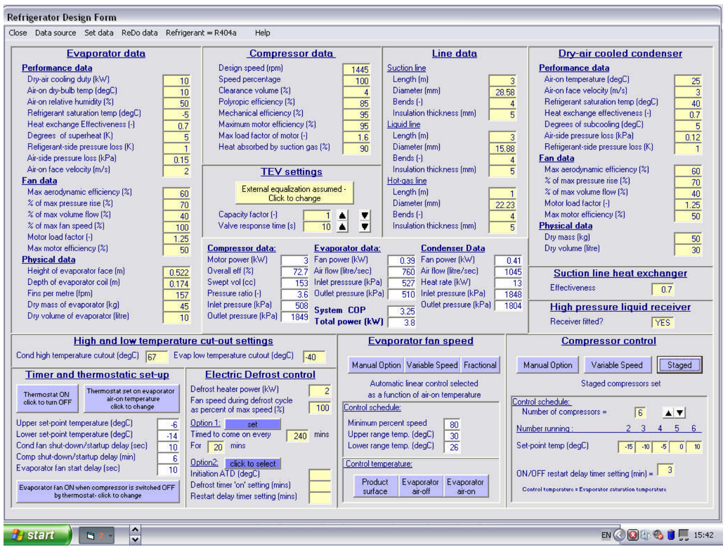


Figure 5: Refrigerator design input screen

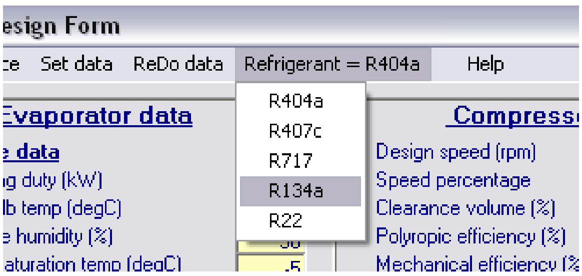


Figure 6: Refrigerant fluid selector accessed through the toolbar

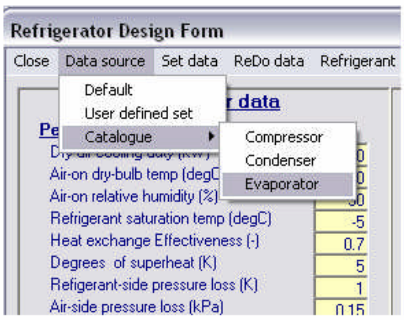
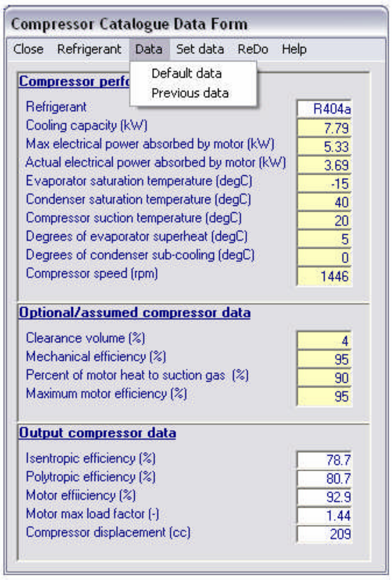


Figure 7: Showing how the catalogue input data functions are accessed through the tool bar



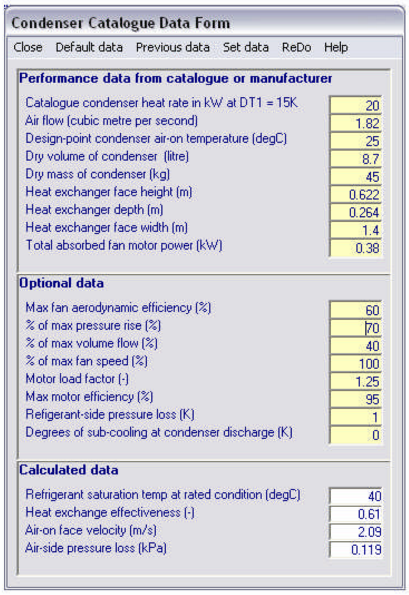


Figure 8: Showing the Compressor catalogue data form

Figure 9: Showing the condenser catalogue data form

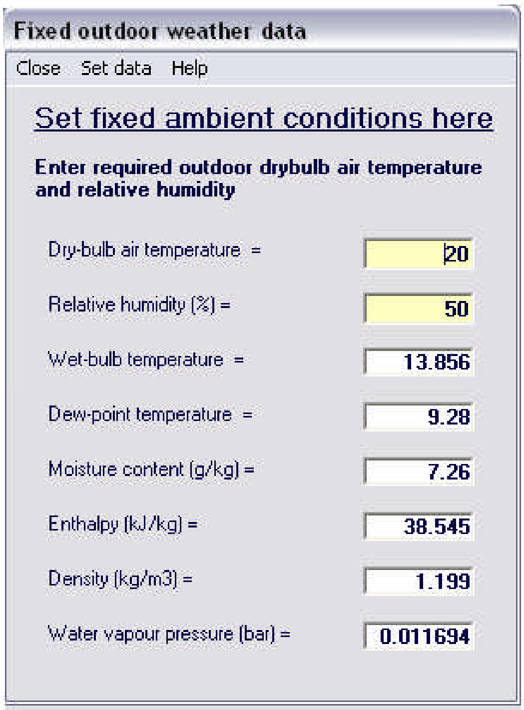
The refrigerator design screen also allows users to choose between from a range of system control options, including:

- Six system thermostat control options
- Three evaporator fan speed control options (manual, automatic variable and automatic fractional)
- Three compressor control selections, (manual speed control, automatic speed control based on temperature and staged, with up to six compressor stages available)
- Two automatic electric defrost control options,(set either on by time and on by ATD)
- High and Low Temperature cut-out controls
- Compressor and fan motor start-up delay controls.

In addition user can alter the time-constant and cooling capacity of the thermostatic expansion value to simulate the effects of both a badly positioned sensing bulb and an over or undersized valve, resulting in valve hunting and evaporator flooding.

Outdoor ambient conditions: VCR software allows users to select between fixed or simulated variable outdoor temperature and relative humidity. The fixed outdoor weather data function requires you to enter only the desired ambient temperature and relative humidity. The screen for this function is shown in Figure10. Although the inputs and outputs of the fixed weather data function are intended for use by the VCR simulator, the calculated output shown in Figure 10 provides useful psychrometric data for moist air.

For the variable weather data option you need select both the location of the plant (from a list of seven major UK mainland cities) and the month of the year for which you wish to simulate its operation. The variable weather screen is shown in Figure 11. With the variable outdoor weather option set, the model simulates the diurnal variation in ambient temperature and humidity ratio. This simulation is based on published whether data for average monthly peak temperatures in seven UK cities taken over 30 years.



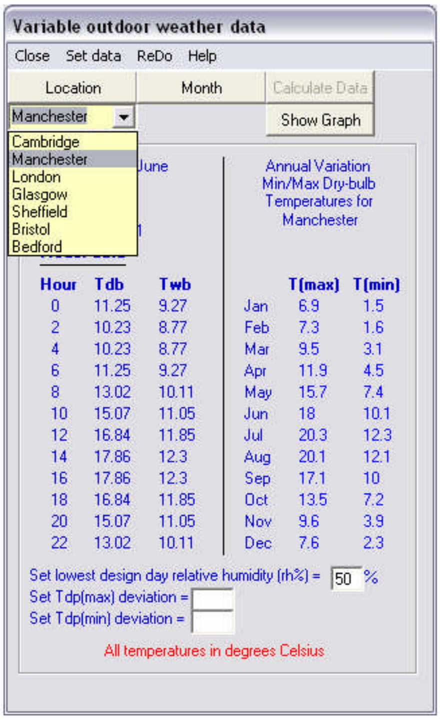


Figure 10: Fixed ambient weather data screen

Figure 11: Variable ambient weather data screen

A graph of wet and dry-bulb temperature for the selected day is provided through the variable ambient weather data screen. An example is shown in Figure 12

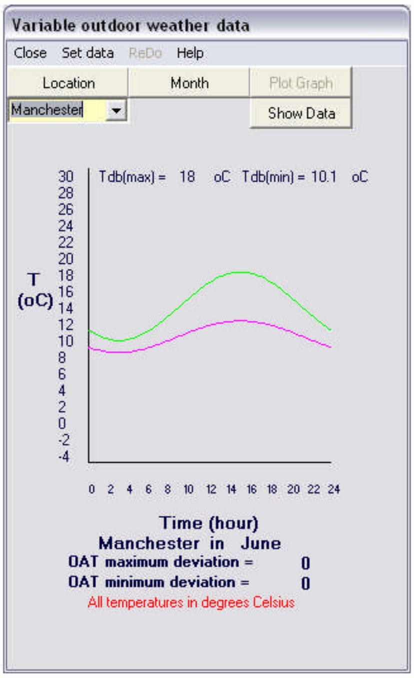


Figure 12: Showing the variation in wet and dry bulb temperature for a June day in Manchester

In the Run-time screen there is a facility which allows all the necessary system design data, which has been entered during a session, to be saved for future use in a user named file. There is a library function provided for saved input data files so that, conversely, if project data has been previously saved it can easily found and reload into the VCR model and RUN without further inputs being required.

The Run-time screen allows model output data to be saved to a user named Excel file for later analysis and assistance in preparing project reports using a 'report generation function' which saves necessary information to a WORD.DOC. Figure 13 shows the data and report saving options available through the Run-time screen toolbar

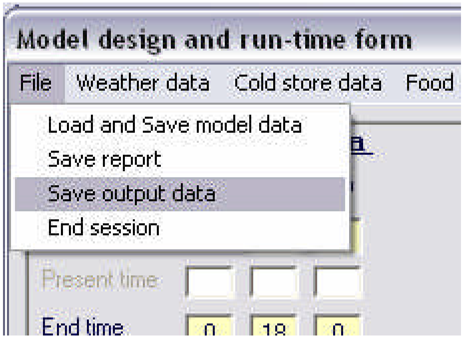


Figure 13: Showing data and report saving options

Run-time

Once all the input data needed to run the simulator have been set and the RUN button has been clicked, the Run-time screen acts as both a control and instrument panels. It displays in 'model' time the instantaneous values of output data, such as evaporator cooling effect, ambient temperature, energy consumption and power values as well as performance data such as instantaneous COP and COSP values. Continuously updated graphical output of selected operating parameters is also provided through the Run-time screen. Depending upon the configuration of the compressor and evaporator fan controls (discussed below), the Run-time screen provides a facility to manually vary compressor and fan speeds in order to allow a user to investigate the effects of varying these important part-load parameters.

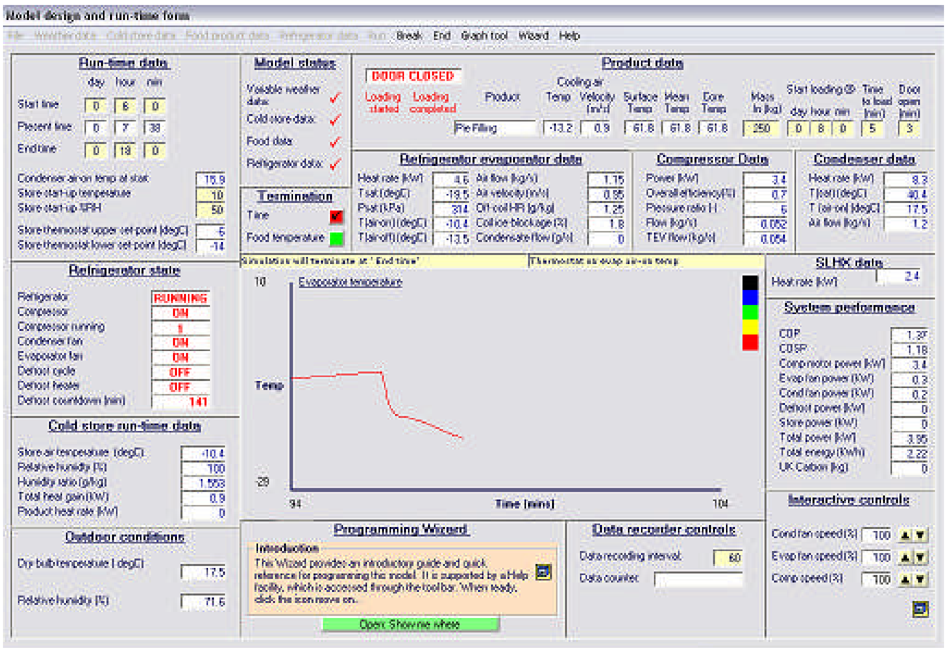


Figure 14: Run-time screen during run-time

Further information

Further information and copies of VCR software are available from ianweames@aol.com