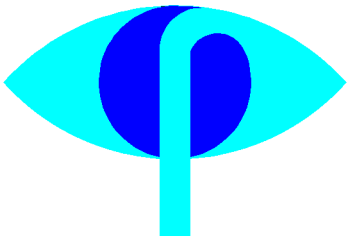
VOLTRA

& SECTRA

computer program to calculate
3D & 2D transient heat transfer
in objects described in a rectangular grid
using the energy balance technique

version 8.0w



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CHAPTER A INTRODUCTION

A.1. Short description of VOLTRA & SECTRA

VOLTRA is a thermal analysis program for transient heat transfer in three-dimensional rectangular objects. VOLTRA is an extension for time-dependent boundary conditions of TRISCO (for steady-state heat transfer).

VOLTRA can be used to carry out fire simulations (with use of the RADCON module). Radiative heat transfer becomes more important when temperature differences increase. The RADCON module allows to include the simulation of non-linear radiation based on geometric view factors. The thermal conductivity and specific heat of materials may be temperature dependent. Latent heat is modelled through an increase of specific heat within a small temperature interval around the change of phase temperature.
Heat transfer to objects via (time dependent) ventilation between zones at different temperatures can be studied.
Dynamic solar heat gains can be studied (since version 6). To this end a solar processor is built in (which requires the use of the RADCON module). An object image with shadows cast by direct sun light at any time and any geographic location can be viewed. The direct and diffuse solar radiation from climate data (e.g. as given in the European Test Reference Years) is cast on the material surfaces. The absorbed solar radiation is converted to time dependent node powers, as additional boundary conditions to the system. Transmission of solar radiation is possible via transparent materials to simulate heat gains through windows. The reflected solar radiation is diffuse and distributed according to the view factors (calculated with the RADCON module) to other material surfaces. Direct radiation is reflected (as diffuse radiation) using a reflection factor which may be function of the angle of incidence.
Controls are available (since version 8) to replace boundary condition functions or material property functions with other functions, based on sensor temperature target functions.

The object modelling is completely identical as in TRISCO. A TRISCO data file, BISTRA data file, BISCO data file or bitmap (BMP file) can be taken as starting data in VOLTRA.
This manual is an extension of the TRISCO manual. First read the TRISCO manual before reading the VOLTRA manual.

The time-dependent boundary conditions are described with functions, either built-in functions based on parameters, or external user-defined functions based on function values given at a fixed time interval.
The thermal conductivity, specific heat and reflection factor of a material can refer to functions described in external text files: thermal conductivity as a function of temperature, specific heat as a function of temperature, solar reflection factor as a function of angle of incidence.

VOLTRA allows creating time-dependent graphic animations of moving shadow patterns, calculated temperature field and heat flux field in the studied object. Alphanumeric lists of time functions of temperatures in individual nodes or heat flows through given surfaces through the object can be made. Graphs using the text output data can be drawn e.g. in Microsoft Excel.

SECTRA (or VOLTRA-2D) is a two-dimensional reduced version of VOLTRA. It is the transient counterpart of the program KOBRU86 (or TRISCO-2D) for 2D steady-state heat transfer.

The RADCON module, which allows a better simulation of radiation (using view factors) and convection, is available in VOLTRA (from version 3), and is required for fire simulation and use of the solar processor.

A.2. Program releases history

VOLTRA v1.0 dates from May 1993.

VOLTRA v3.0w (December 2001) is the first Windows version:
- Developed for Microsoft Windows (Windows 95, Windows 98, Windows NT, Windows 2000, and upwards).
- Through another system solution technique, much larger systems can be solved. The node capacity is of the same order of magnitude as in TRISCO: 1 000 000 nodes and more.
- The calculation is at least 50 times faster.
- The RADCON module can be used.
- Most of the functionality of the Windows version of TRISCO (i.e. from version 8 up) is also available in VOLTRA (e.g. choice of language, 3D preview of the geometry when selecting data files, image feedback window, zoom functions, block transformations, automatic calculation of equivalent thermal conductivities of cavities and convective heat transfer coefficients in air cavities, batch calculation, output bitmaps with user-defined resolution).
- Built-in converter to import data from previous SECTRA and VOLTRA versions and from TRISCO (from version 8 up).
- A graphic preview of the internal function definitions is possible.
- The concept of line and plane definitions is changed into the definition of output blocks.
- Intermediate solution files can be saved on hard disk, and are useful for the production of animation sequences from different points of view.
- *.avi files of graphic animations with a user defined resolution can be written. These .avi files can be viewed using Windows Media Player or another tool.
- Graphs of temperature or heat flow courses as a function of time are not directly possible within VOLTRA, but can be made e.g. using Microsoft Excel.

VOLTRA v3.1w (December 2002) contains the following extensions (to be compatible with TRISCO v10.0w):
- Two new types of boundary conditions:
  1. Enclosures with unknown temperature and global surface heat transfer coefficient (type BC_FRE_S).
  2. Border faces between colours having a fixed temperature function course or heat flux function course (“borderface BCs”).
- New split mesh functions (Grid > Split Mesh max… and Grid > Split All max…).
- Graphical feedback in the Image window of a selected item in another edit window can be toggled on or off (Image > Hide Selection Outline).

VOLTRA v4.0w (April 2003) contains the following additions:
- Temperature dependent material properties (thermal conductivity, specific heat), which are useful in e.g. fire simulations.
- Simulation of ventilation flows through different air zones following one or more user-defined paths. The ventilation flow rates can change in time as defined in ventilation time functions. The simulation of ventilation flows allows the study of heating and cooling of objects due to ventilation systems.
- Possibility of different convection nodes (related to different colours) in one air cavity, useful e.g. for the simulation of a ventilation flow through a chimney.

VOLTRA v5.0w (September 2005)

- Contains functionality of TRISCO v11.0w (easier input editing & better graphic feedback).
- New type of material (requires RADCON module): transparent material (conduction + radiation), useful for small air cavities of irregular shape (instead of materials of type EQUIMAT).
- New type of boundary condition: material with given temperature (function) or heat power density.
- No function references required for constant numeric input values.
- Function Graph window as visual feedback of the input in the Functions window, with zoom facilities.
- Image window: interactive view of temperature value (after calculation) at cursor location per time step.
- Undo/redo edit actions.
- View factors calculation: view factors in a fine grid can be obtained through interpolation of view factors in a coarser grid (to overcome the quadratic proliferation of view factors in a fine calculation grid).
- Graphic output:
  clip colours (to hide certain material layers, to get a better inside view of the object);
  view heat fluxes in material cutoff planes.

VOLTRA v6.0w (September 2006) contains the solar processor.

- Same solar radiation boundary condition data files as in CAPSOL (global and diffuse radiation on a horizontal surface).
- Input required of north orientation.
- Calculation of sun position and visualisation of shadows cast by direct sun light.
  Creation of AVI animation file of shadows over calculation period.
- Additional material properties required: reflection factor (may be a function of the angle of incidence), transmission factor (to indicate a transparent material).
- Calculation and visualisation of absorbed solar fluxes on material surfaces due to solar radiation (requires the use of the RADCON module).
  Direct solar radiation on an exterior material surface depends on geographical location, solar radiation climate data, day of year, clock time, surface orientation.
  Diffuse solar radiation on an exterior material surface depends on the view factor to the open sky and is calculated using Muneer's radiation model (also used in CAPSOL).
  Reflected radiation (of direct and diffuse incident radiation) at an exterior material surface is lost (as in CAPSOL). An input parameter ("ground reflection factor") allows to take into account the reflected radiation from the environment.
  Radiation on transparent materials are transmitted to internal zones.
  Direct radiation is projected on internal walls following the solar rays.
  Diffuse radiation is distributed on all internal walls proportional to the view factors.
  All reflected radiation at an interior material surface is diffuse and is redistributed to the other interior surfaces proportional to the view factors.
  The scheme of successive internal reflections and transmissions is solved using a radiosity method.
  The view factors can be obtained from a prior view factor calculation using a coarser grid (to speed up the processing time and reduce the required memory space).
  The absorbed solar fluxes can be output to an AVI animation file or output to a text file.
- The absorbed solar fluxes can be used as boundary conditions for a thermal simulation (calculation of temperatures). In this way solar heat gains on the thermal behaviour of a construction can be studied.

– The format of view factor file is modified.

VOLTRA v6.1w (April 2008)
– Solar processor adapted to use of 2D geometries (SECTRA).
– Adjust coordinates of output nodes and output blocks after any grid operation.

VOLTRA v6.2w (May 2009)
– Diffuse solar reflection also possible in solar zone (of type BC_SKY).
– Sun obstacles (as in CAPSOL and BISTRA), defined as sky hemisphere regions, which block direct solar irradiation and decrease diffuse solar irradiation.
– Import BISTRA data.

VOLTRA v6.3w (December 2009)
– Improved more stable calculation of systems with ventilation flows.

VOLTRA v7.0w (March 2012)
– Default data file Voltra.vtr with initialisation values for thermal properties per colour.
– Time dependent functions for thermal conductivity, total surface heat transfer coefficient and convective heat transfer coefficient.
– Functions compatible with TRISCO v12.0w: automatic split for grid refinement; equivalent thermal conductivities for cavities with different surface emissivities.
– Show temperature or heat flux under the cursor in the graphic output.
– 3D visualisation of sun position at any time step.
– Show temperature profile along a grid line at any time step.

VOLTRA v8.0w (May 2017)
– Functions compatible with TRISCO v14.0w: recalculation of blocks (*Blocks > Arrange Blocks…*); clip blocks (*Blocks > Reduce to Clip…*); detect void space (*Blocks > Convert Void to Blocks*); show materials as transparent blocks (*Image > Show Transparent*), display grid unit; simulation of adiabatic surface of transparent material (type TRANSMAT), graphic output of single isothermal line.
– Show north direction and sun paths (function *Image > Show North* from main menu) and sun position (function *View > Sun Position* from graphic output window).
– Controls which allow to replace boundary condition functions (temperature, heat power, heat flux, heat transfer coefficient, ventilation) or material property functions (thermal conductivity, infrared emissivity, solar reflection factor, solar transmission factor) with other functions (of the same type), dependent on the temperature in a sensor node compared to a temperature target function (of time) and desired heating or cooling.
  The replacement of a ventilation function can also be dependent on a minimum required temperature difference between two ventilation zones.
– Control functions can also refer to constant functions.
  The constant function is reintroduced as function type in the Functions window.
– The infrared emissivity of a material surface and the solar transmission factor of a material can be a function of time (intended for use with controls, e.g. for the simulation of solar screens).

A.3. Minimum system requirements

– VOLTRA is a 32-bit Windows program (which can also be run from Windows 64-bit).
  VOLTRA 32-bit is installed (on Windows 7) in C:\Program Files (x86)\Physibel\Voltra.
  In this folder the executable file is Voltra.exe.

– 512 Mb RAM allows to solve a system of about 1,000,000 nodes.
  1 Gb RAM allows to solve about 3,000,000 nodes.
  The maximum usable memory space of the 32-bit program is limited to 2 Gb (even if more RAM is installed).
– VOLTRA relies on OpenGL for use of hardware accelerated graphics.
– A software licence of VOLTRA is protected by a hardware key, provided by Physibel to the end user. The demo version of VOLTRA is not protected.

A.4. VOLTRA 64-bit

A 64-bit version of VOLTRA is available as an option.
VOLTRA 64-bit is installed in C:\Program Files (x86)\Physibel\Voltra64.
In this folder the executable file is Voltra64.exe.
The memory space of the 64-bit program is limited to the installed RAM (which may be larger than 2 Gb).

The Physibel 64-bit programs need several shared libraries (.dll files) from Microsoft.
The Microsoft Visual C++ 2017 Redistributable Package (x64) can be downloaded from https://support.microsoft.com/en-us/help/2977003/the-latest-supported-visual-c-downloads.
This package installs mfc140.dll and other files in the directory C:\Windows\SysWOW64, required by 64-bit applicatons developed with Microsoft Visual C++ 2017.

Data folder (from Windows 7)
From Windows 7 it is strongly recommended to move the installed data folder (C:\Program Files (x86)\Physibel\Voltra\Data) to a location out of C:\Program Files (x86), e.g. C:\Physibel\Voltra\Data.
Otherwise for new or modified data files a virtual folder (invisible within VOLTRA) will be used, e.g. C:\Users\User\AppData\Local\VirtualStore\Program Files (x86)\Physibel\Voltra\Data.

Differences of VOLTRA64 compared to the 32-bit program VOLTRA
– During file selection in the File Open dialog box (using *File > Open…*) no graphic data preview is available.
– From the the Graphic Output menu only PNG files can be saved (using *File > Save As…*).
  No BMP files can be saved as in the 32-bit program.
– No graphic output can be printed directly from the the Graphic Output menu
  (there is no function *File > Print…*).
– No AVI files can be created from the Graphic Output menu
  (i.e. there is no function *File > Write AVI File…*).

A.5. Overview of delivered files and file structure

VOLTRA is installed (when the user has accepted the default destination) in the folder C:\Program Files (x86)\Physibel.

The following files are installed, or created when using VOLTRA:

Folder	*File*	*Description*
…\Physibel\Voltra	Voltra.exe	VOLTRA (32-bit) program
	Sectra.exe	SECTRA (32-bit) program
	Funcedit.exe	Function editor
	Voltra.prm	Program parameters
	Voltra.vtr	Template data file read at start up of VOLTRA
	*.dll, *.pat, *.rgb	Program resources

…\Physibel\Voltra\Data	*.vtr	VOLTRA data files
	*.fte, *.fem, *.fir, *.ffh, *.fvr, *.fsg, *.fsd, *.fht, *.fco, *.fla, *.fce,	
	*.frf, *.ftr	Function files
	*.vwf	Calculated viewfactors (with RADCON)
	*.sfd, *.sfx	Calculated absorbed solar fluxes (RADCON)
	*.sol	Calculated node temperatures
	*.flx	Calculated fluxes (with RADCON)
	*.png, *.bmp, *.avi	Graphic output files
	*.txt, *.doc	Text output files
…\Physibel\Voltra64	Voltra64.exe	VOLTRA 64-bit program
	*.dll, *.pat, *.rgb	Program resources
…\Physibel\Materials	*.phm	Material databases
	MatEdit.exe	Material editor
	MatEdit.prm	Material editor program parameters
	*.dll, *.pat	Material editor resources
…\Physibel\Manuals	VoltraManual.pdf	VOLTRA manual
	MatEditManual.pdf	Material editor manual

CHAPTER B INPUT DATA

B.1. Program example

Data file: PilotexVoltra.vtr (installed in the directory …\Physibel\Voltra\Data).
(In SECTRA: PilotexSectra.vtr – which is a 2D example, but analogous to the VOLTRA example treated here.)

Construction
The program example "Pilotex" from the TRISCO manual (data file Pilotex.trc) is taken as starting data for this program example of VOLTRA (with final version in PilotexVoltra.vtr).
The TRISCO data can be entered into VOLTRA using the command *File* > *Open*….
Choose the file type: TRISCO Data Files (*.trc).
Look in the directory …\Physibel\Voltra\Data.
Then open Pilotex.trc.
The screen shows a windows layout (with Image window, Grid window, Blocks window and Colours window) similar as in TRISCO.

The Colours window (with thermal properties of materials and boundary conditions) shows two new columns for dynamic material properties:
- material density ρ in kg/m^3
- specific heat c in J/(kg.K)

The initial default values (1000 kg/m^3 and 1000 J/(kg.K)) should be modified by the user to the true values as in the figure below.

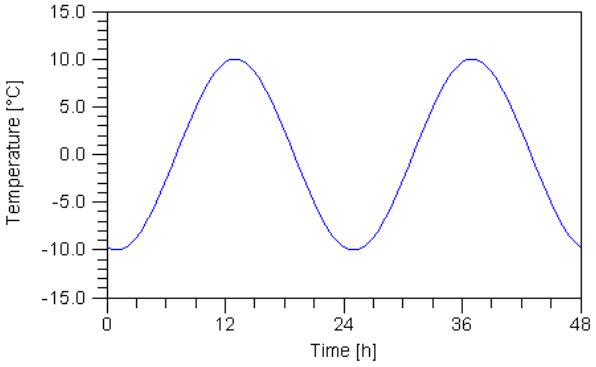
Colours

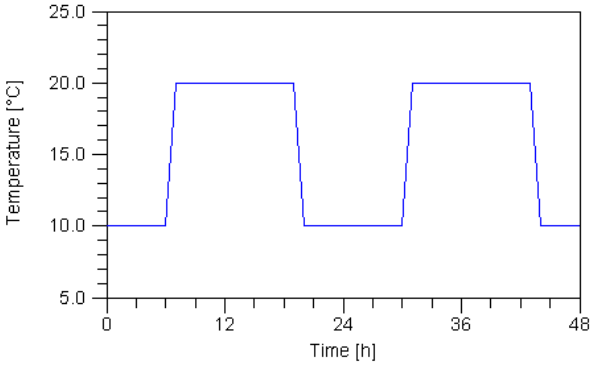
Col.		Type	CEN-rule	Name	Pat.	λ [W/mK]	ε [-]	ρ [kg/m³]	**c [J/kgK]**	θ [°C]	h [W/m²K]	q [W/m²]
2		BC_SIMPL	NIHIL	exterior						0.0	25.00	0
3		BC_SIMPL	NIHIL	interior						20.0	5.00	0
4		MATERIAL		outer leaf cavity wall		1.000		1750.0	840.0			
5		MATERIAL		wall insulation		0.035		40.0	840.0			
6		MATERIAL		inner leaf cavity wall		0.700		1400.0	840.0			
7		MATERIAL		concrete		2.500		2200.0	840.0			
9		MATERIAL		roof insulation		0.030		40.0	840.0			

At the right border of the Colours window (not visible in the above figure; use the horizontal scroll bar) also three new columns are present for use of the solar processor (not relevant in this example).

Dynamic boundary conditions
The inside and outside temperatures are supposed to vary with time:
- The outside temperature is a sine with mean value 0°C, amplitude 10°C, period 1 day and start at 7 h.
- The inside temperature also has a period of 1 day:
  a constant value of 20°C between 7 h and 19 h;
  a constant value of 10°C between 20 h and 6 h;
  linearly interpolated temperatures in the transition periods (from 6 h till 7 h, and from 19 h till 20 h).

Below are the graphic representations of both temperature functions (showing 2 days).





The function courses are defined in the Functions window (opened with *Edit* > *Functions*).
Add the first function via the command *Edit* > *Insert After*.
The function reference (2nd column) is initialised as "T01", which is OK (the letter "T" refers to a temperature function; "01" is a sequence number).
The function type must be modified into "SINE" (via several double clickings upon the cell, or pressing <Enter> when the cell is active). Then enter the function parameters in the following columns (the specific meaning of each value is explained in the status bar) as in the figure below.
All time parameters must be entered in minutes (e.g. 1 day = 24 h x 60 min/h = 1440 min).
A graphic representation of the edited function is shown in the Function Graph window (cf. picture above left).
Then add the second function via *Edit* > *Insert After*.
The function reference "T02" is OK.
The function type must be modified into "STEP2", which is the generic name for the wanted periodic step function. Enter the parameters according to their meaning as explained in the status bar. (Note the same function can be defined using other parameters, exchanging level 1 and 2; the parameters are then: 20, 10, 1440, 720, 60, 420.)

Functions

No.	Ref.	Type	Filename	Prm.1	Prm.2	Prm.3	Prm.4	Prm.5	Prm.6
1	T01	SINE		0	10	1440	420		
2	T02	STEP2		10	20	1440	600	60	1200

Function references

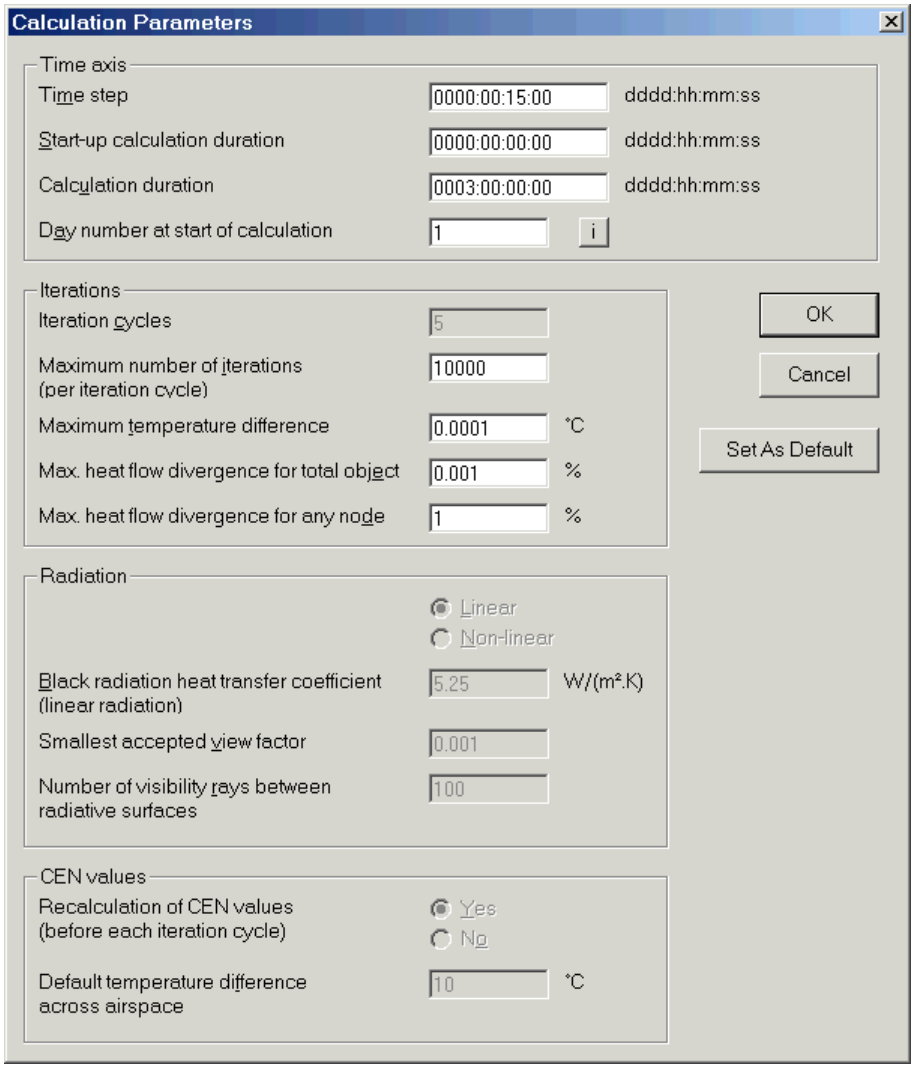
The temperature fields of the inside and outside boundary conditions (i.e. colours 2 and 3) in the Colours window must be modified to refer to the just defined functions via the given function references ("T01" and "T02").

Colours

Col.		Type	CEN-rule	Name	Pat.	λ [W/mK]	ε [-]	ρ [kg/m³]	c [J/kgK]	θ [°C]	h [W/m²K]	q [W/m²]
2		BC_SIMPL	NIHIL	exterior						T01	25.00	0
3		BC_SIMPL	NIHIL	interior						T02	5.00	0
4		MATERIAL		outer leaf cavity wall		1.000		1750.0	840.0			
5		MATERIAL		wall insulation		0.035		40.0	840.0			
6		MATERIAL		inner leaf cavity wall		0.700		1400.0	840.0			
7		MATERIAL		concrete		2.500		2200.0	840.0			
9		MATERIAL		roof insulation		0.030		40.0	840.0			

The following calculation parameters are set in the Calculation Parameters dialog box (opened with *Edit > Calc Parameters…*):

- Time step interval: 15 minutes.
- Start-up calculation duration (to get "dynamic" start values): 0 seconds.
- Calculation duration: 3 days.
- Day number at start of calculation: 1 (i.e. the default value). This item is only relevant when climatic data files (e.g. test reference years) are used.



The calculation is started using the command *Calc > Calc System*. The input data is saved automatically (under the name Pilotex.vtr). During the calculation the temperature field of the previous calculated time step is shown in the Image window, and updated every new time step.

At the end of the calculation the calculation results as in TRISCO are available for the last time step. The graphic output can be found via *Output > Graphic Output*, the text output via *Output > Text Output*. Intermediate time step solutions can be examined if the option "Save step solutions to disk" was enabled before starting the calculation, in the dialog box opened with *Calc > Save Frequency…*. Be careful that your PC disk has got enough free memory: every solution file has a file length of about 195 Kbytes (for the given input data). If you save the solution files every time step, all solution files together take about 55 Mbytes. When a set of solution files is saved on disk, also graphic animations can be produced. An animation file PilotexVoltra.avi as created with VOLTRA is available on the distribution disk, and can be viewed using e.g. Microsoft Media

Player.

In the Text Output window (result of *Output > Text Output*) a report table can be shown using the command *View > Report Output*, containing temperatures or other thermal properties in given locations at given time step intervals. The report items are defined in the Report Definition window, opened in the main program menu via *Edit > Report Definition*. Some report items may refer to output nodes as defined in the Output Nodes window (opened using *Edit > Output Nodes*), or to output blocks as defined in the Output Blocks window (opened using *Edit > Output Blocks*). The file PilotexVoltra.vtr contains a report definition, for which a text report can be produced (after calculation) at a given report frequency time interval space (defined in the dialog box opened with *Calc > Report Frequency…*).

This example has given a quick tour around some input and output possibilities of VOLTRA. Other example data files (containing other topics as e.g. ventilation flows) can be found in the data folder.

B.2. VOLTRA start up

When VOLTRA is launched, the parameter file Voltra.prm is read (if present) to load global program settings.
Then the default data file Voltra.vtr is read (if present) to initialise material and surface boundary condition properties of the Colours window, which is useful to minimise the input for new data files.
At installation Voltra.vtr is a copy of the template data file "template_general_v2015_vtr.vtr".
The files Voltra.prm and Voltra.vtr must be in the same directory of the program Voltra.exe (…\Physibel\Voltra).
There is no visual feedback in the initial screen of VOLTRA to indicate that Voltra.prm and/or Voltra.vtr are loaded.

B.3. The Functions window

For the time dependent boundary conditions VOLTRA refers to time functions: either an internal function, or an external function.
An internal time function is a built-in program function, defined by one or more parameters.
VOLTRA contains 6 built-in functions, which are described further in this section.
An external time function is defined in a separate data file, with extension:
- .fte (temperature function)
- .fht (surface heat transfer coefficient function)
- .ffh (power function)
- .fir (imposed flux function)
- .fco (time dependent thermal conductivity function).
- .fem (infrared emissivity function)
- .ftr (solar transmission factor function)
- .fsg (horizontal global solar radiation function)
- .fsd (horizontal diffuse solar radiation function)
- .fvr (ventilation function)

The program FUNCEDIT (cf. Chapter F) allows to edit these files.

Some material properties (thermal conductivity, specific heat, solar reflection factor) may be dependent on another property (temperature, angle of incidence).
These temperature functions (thermal conductivity, specific heat) or angular functions (solar reflection factor) are defined in separate data files, with extension:
- .fla (temperature dependent thermal conductivity function)

– .fce (temperature dependent specific heat function)
– .frf (angular dependent solar reflection factor function).

These function data files are text files consisting of two or more text lines:

x0 y0
x1 y1
x2 y2
…
xn yn

with $x0 \leq x1 \leq x2 \leq \ldots \leq xn$.
Each text line consists of two float numbers, the abscissa (i.e. a temperature value or an angle of incidence) and the ordinate (i.e. the corresponding thermal conductivity, specific heat value or solar reflection factor) of a characteristic point of the function. The function is linearly interpolated between the characteristic points. If $x < x0$, then $y = y0$. If $x > xn$, then $y = yn$.
The user can define these functions with a text editor (e.g. Windows Notepad).

All functions that are used in a VOLTRA data file, are defined in the Functions window, opened with the command *Edit > Functions*.
Each function is defined by:

– A function reference name:

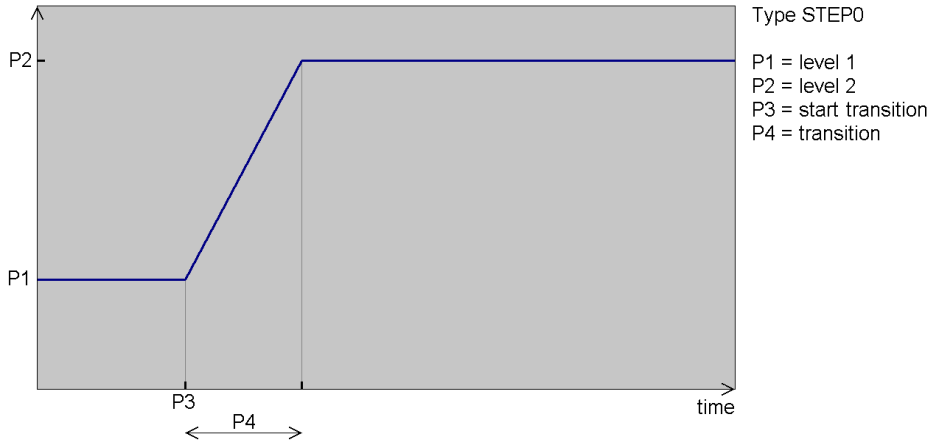
C01 up to C99	for a specific heat function (temperature dependent)	(in J/(kg.K))	*.fce
D01 up to D99	for a horizontal diffuse solar radiation function (only D01 is used in the Solar Data dialog box)	(in W/m^2)	*.fsd
E01 up to E99	for an infrared emissivity function	(dimensionless)	*.fem
G01 up to G99	for a horizontal global solar radiation function (only G01 is used in the Solar Data dialog box)	(in W/m^2)	*.fsg
H01 up to H99	for a surface heat transfer coefficient function	(in W/(m².K))	*.fht
I01 up to I99	for an imposed flux function	(in W/m^2)	*.fir
L01 up to L99	for a thermal conductivity function (temperature dependent)	(in W/(m.K))	*.fla
M01 up to M99	for a thermal conductivity function (time dependent)	(in W/(m.K))	*.fco
P01 up to P99	for a power function	(in W)	*.ffh
R01 up to R99	for a solar reflection factor function (angular dependent)	(dimensionless)	*.frf
S01 up to S99	for a solar transmission factor function	(dimensionless)	*.ftr
T01 up to T99	for a temperature function	(in °C)	*.fte
V01 up to V99	for a ventilation function	(in m^3/s)	*.fvr

Function reference names can be used in:
the Colours window (columns with header λ, ε, c, θ, h, q, θa, hc, Pc, θr, ρs, τs),
the Node BCs window (columns with header θ and P),
the Borderface BCs window (columns with header θ and q),
the Material BCs window (column with header θ and p),
the Ventilation Flows window (column with header "Flow"),
the Controls window (columns with header "θ target", "Function from", "Function to").

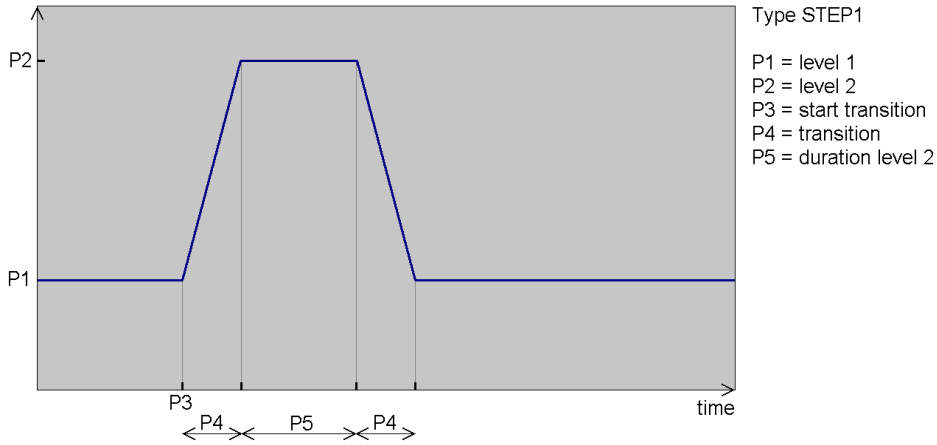
– A function type: a toggle with values FILE, CONST, STEP0, STEP1, STEP2, SINE and SINPOS.
Temperature functions (L## and C##) and solar reflection factor functions (R##) can only have

type FILE.

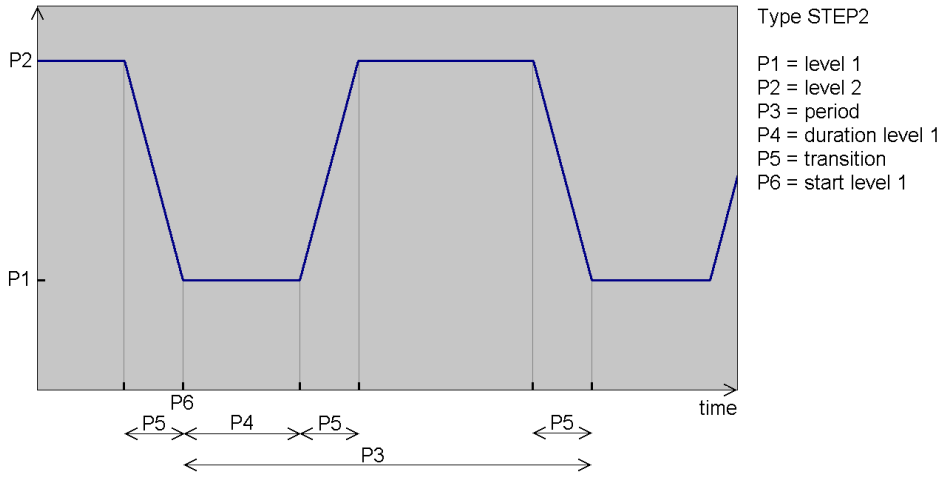
FILE	for a function defined in an external function file
CONST	for a constant function, defined by 1 parameter (P1 = constant function value)
STEP0	for a step function defined by 4 parameters (P1,P2,P3,P4)



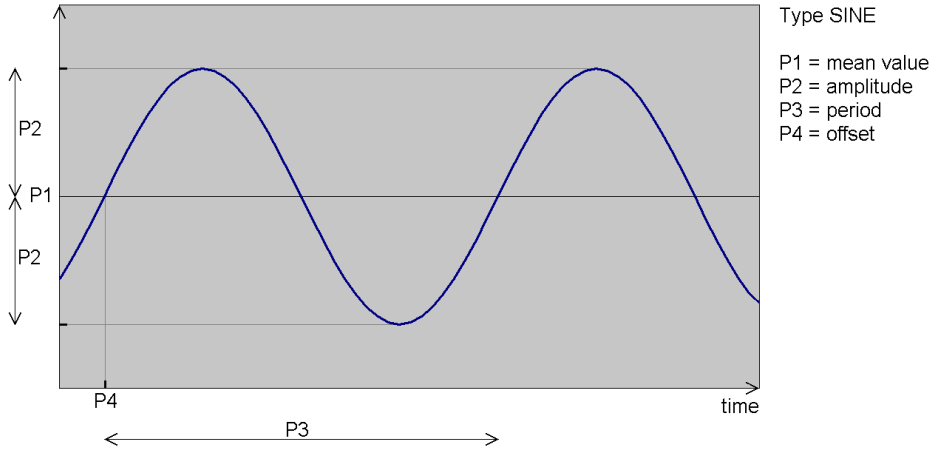
STEP1	for a step function defined by 5 parameters (P1, P2, P3, P4, P5)



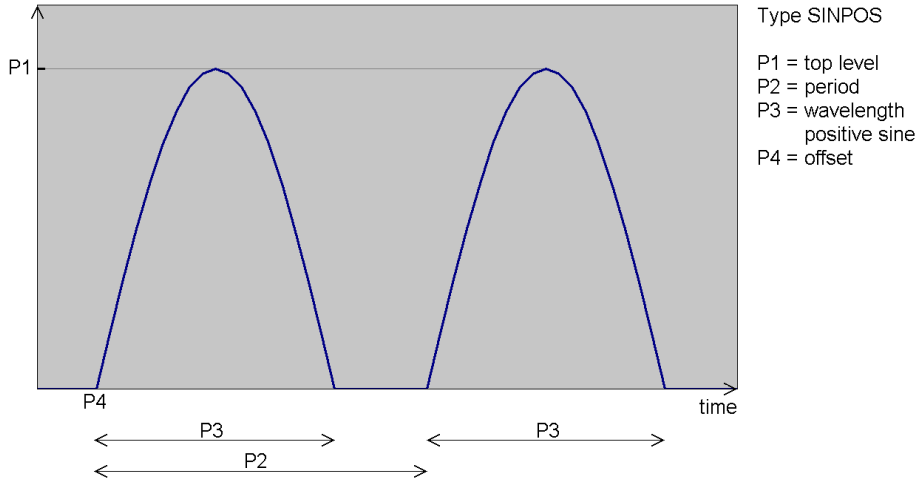
STEP2 for a (periodic) step function defined by 6 parameters (P1, P2, …, P6)



SINE for a sine function, defined by 4 parameters (P1, P2, P3, P4)



SINPOS for a positive sine function, defined by 4 parameters (P1, P2, P3, P4)



– A function filename for an external function file (i.e. of type FILE).
When this field is double clicked (or when <Enter> is pressed), a file path can be chosen in the Open dialog box.
It is recommended to store the external files in the same directory as the VOLTRA data file

(because then only the function file name is saved in the .vtr file, so that copying of the .vtr file together with the function files to another directory has the desired result that the new .vtr file refers to the function files in the same new data directory).

– Function parameters for internal functions (of type CONST, STEP0, STEP1, STEP2, SINE or SINPOS). The meaning of each parameter per function type is explained in the status bar (cf. also the figures above).

A new function can be inserted via *Edit > Insert Before* or *Edit > Insert After*.
The current function can be deleted via *Edit > Delete*.

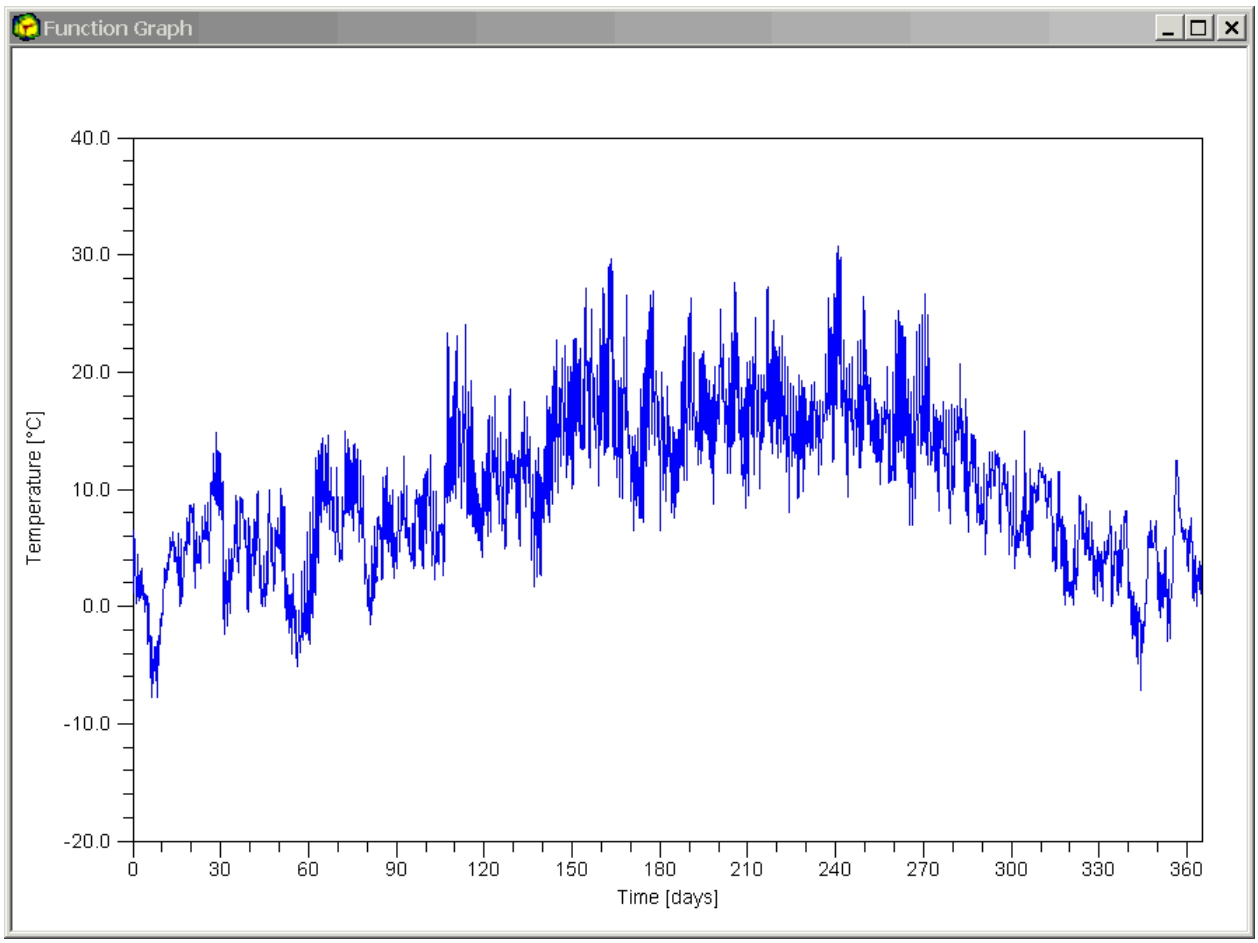
B.4. The Function Graph window

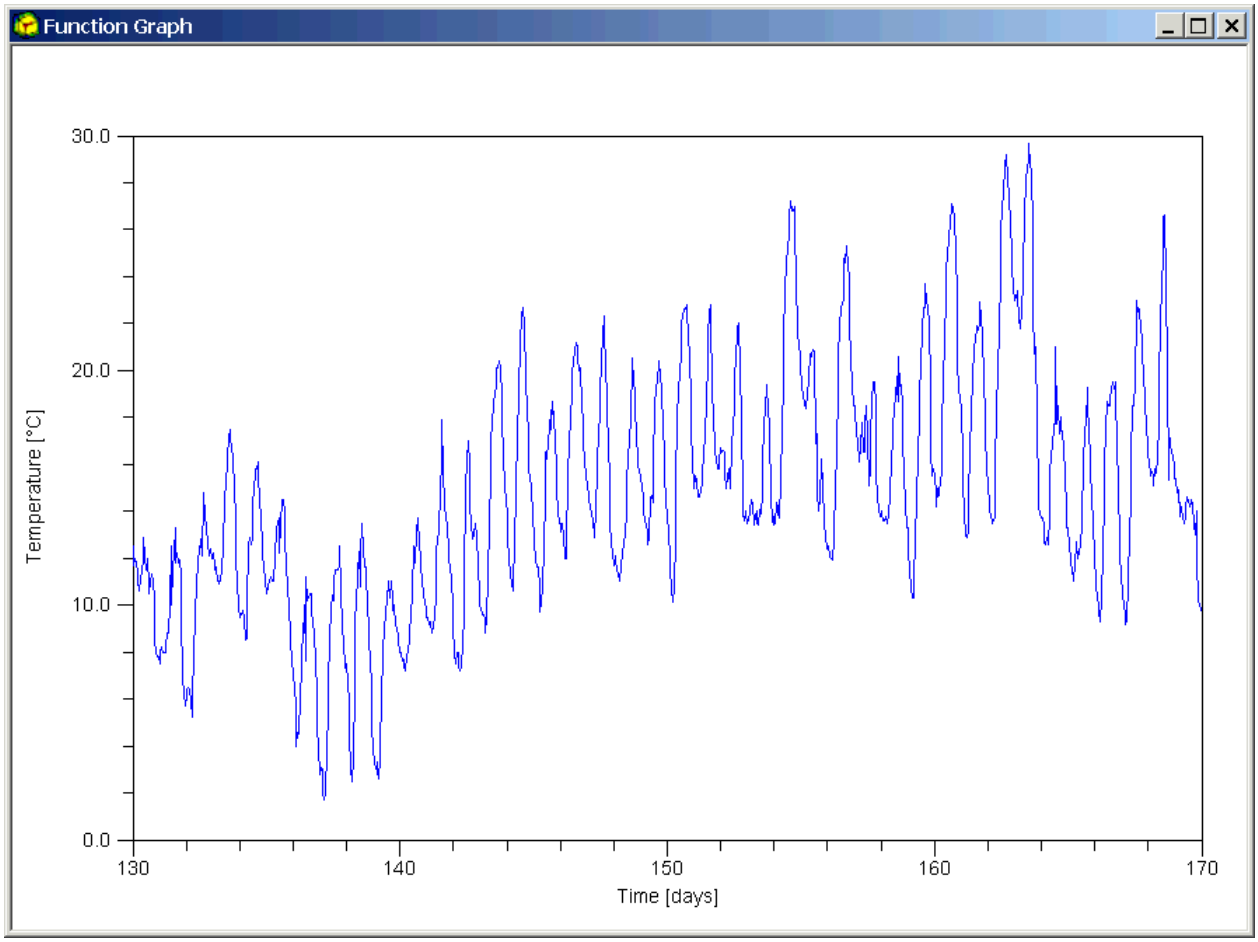
The Function Graph window shows a graph of the current function in the Functions window.
The Function Graph window is automatically opened when the Functions window is activated, and automatically closed when another window is activated (e.g. Grid window or Colours window).

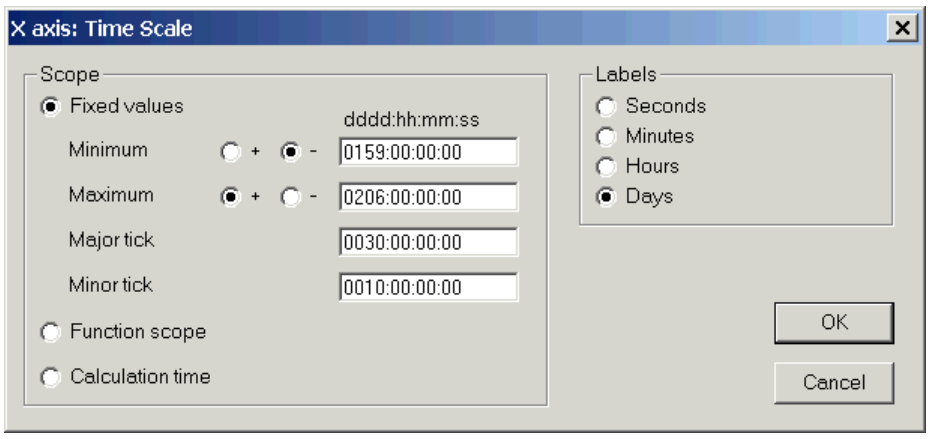
The first figure below shows the initial Function Graph window for a temperature function that refers to the external file UCL.FTE (test reference year with hourly temperatures for Uccle, Belgium).

Zoom functions (via the Image submenu: *Image > Pan*, *Image > Zoom Window*, *Image > Zoom In*, *Image > Zoom Out*, *Image > Zoom Total*, *Image > Previous View*) are available to view function details. The second figure below shows an example (fragment from UCL.FTE).

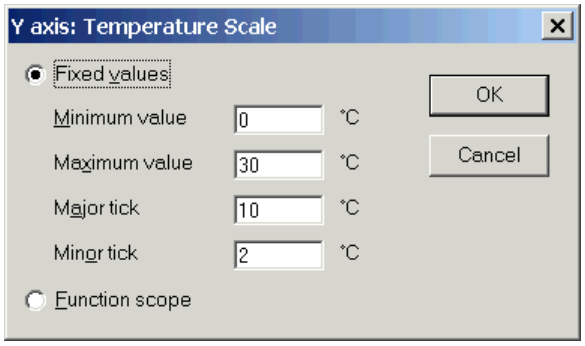
The X and Y axis tic marks and labels can be redefined via the commands *Functions > X Scale…* and *Functions > Y Scale…*. The third and fourth figures below show the opened dialog boxes. The quantities defined by the X axis (time, temperature, angle of incidence) and Y axis (temperature, flux, power, ventilation rate, lambda, infrared emissivity, specific heat, surface heat transfer coefficient, solar reflection factor, solar transmission factor) are determined by the current function in the Functions window.
The origin of the X axis of a time function (i.e. time = 0) corresponds to the day number at the start of the calculation duration, as defined in the Calculation Parameters dialog box.


Function Graph
40.0
30.0
20.0
10.0
0.0
-10.0
-20.0
Temperature [°C]
0
30
60
90
120
150
180
210
240
270
300
330
360
Time [days]


Function Graph
30.0
20.0
10.0
0.0
Temperature [°C]
130
140
150
160
170
Time [days]



The scope of the time scale on the X axis can be chosen between fixed values, function scope (corresponding to the definition of the function) and calculation time (corresponding to the calculation duration as defined in the Calculation Parameters dialog box).
When fixed values are chosen, the minimum and maximum value (with plus or minus sign), and the major and minor tick distances can be set. Also the label unit can be chosen (seconds, minutes, hours or days).
For the figure above (X axis: Time Scale), the time scope goes from day number –159 up to day number 206. There is a major tick every 30 days, and a minor tick every 10 days. The labels are expressed in days.



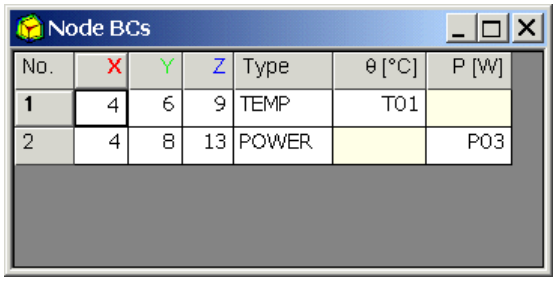
B.5. The Colours window

Compared to the Colours window in TRISCO the following differences occur in VOLTRA:
- Two material properties concerning the thermal capacity are added: the material density ρ in kg/m^3, and the specific heat c in J/(kg.K).
  These properties are also loaded when a material is selected from the material database (via *Colours > Load Material…*).
- Three columns concerning solar radiation are added (at the right border):
  - Sun active status (YES or NO) for a colour of type BC_SIMPL or BC_SKY (to define a *solar zone*, cf. sections C.5 and C.7).
  - Solar reflection factor (for a colour of type MATERIAL): a constant value (between 0 and 1), or a function reference (R##) when the solar reflection factor is a function of the angle of incidence.
  - Solar transmission factor (for a colour of type MATERIAL): a constant value (between 0 and 1), or a function reference (S##) when the solar reflection factor is a function of time.
    The solar transmission factor is applied after subtraction of reflection (which can be dependent on the angle of incidence).

– The properties λ, ε, c, θ, h, q, θa, hc, Pc, θr, ρs and τs can refer to functions (defined in the Functions window) via function reference names.

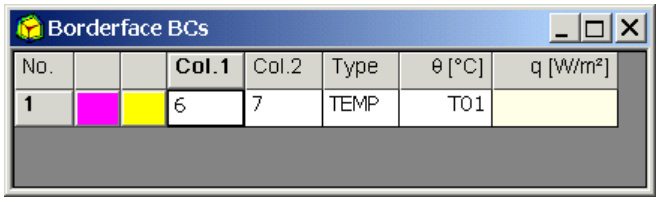
B.6. Node boundary conditions

Node boundary conditions are edited in the Node BCs window, opened with *Edit > Node BCs*.
New node boundary conditions are added using the command *Edit > Insert Before* or *Edit > Insert After*.
The X,Y,Z position refers to a grid node.
The boundary condition properties θ and P can be a numeric value (for a constant property) or can refer to a function (defined in the Functions window) via the function reference name.



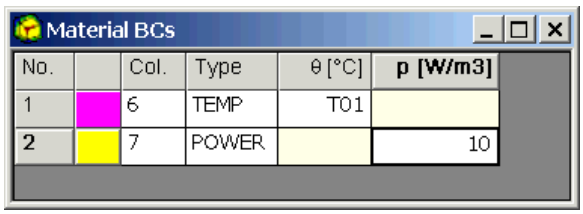
B.7. Border face boundary conditions

In the border face between two different colours (identified by their colour numbers) user-defined temperatures or heat fluxes (as constant values or functions of time) can be imposed. These border face boundary conditions are edited in the Borderface BCs window, opened with *Edit > Borderface BCs*. A new border face boundary condition is added via *Edit > Insert After*.
The type can be "TEMP" (known temperature) or "FLUX" (known heat flux).
The boundary condition properties θ and q can refer to functions (defined in the Functions window) via function reference names (respectively T## and I##, with ## a number from 01 to 99).



B.8. Material boundary conditions

The volume occupied by a material (identified by the corresponding colour number) can have a given temperature or power density. Such a material boundary condition is defined in the Material BCs window, opened with *Edit > Material BCs*.
A new material boundary condition is added via *Edit > Insert After*.
The type is either "TEMP" (known temperature) or "POWER" (known heat power density).
The temperature θ and power density p can be a constant numeric value or a function reference (defined in the Functions window, respectively T## and P##, with ## a number between 01 and 99).
A power density function refers to a power function (defined as .ffh file with unit W), but the unit should be read as W/m^3.



B.9. Unlinked air temperatures in air cavities of type BC_FRE_S or BC_FREE

An air cavity can be modelled using several (adjacent) blocks having different colours. These colours can have different thermal properties (e.g. surface heat transfer coefficient), but must be of the same type (i.e. all BC_FRE_S or all BC_FREE). Otherwise the calculation is immediately stopped, showing the error message "BC (colour …) touches other BC of different type".

Suppose the air cavity is modelled with colours all of type BC_FRE_S. Then all colours get the same (unknown) environmental temperature, which is calculated solving the system. Possible convective heat powers for the individual colours in the same air cavity (column Pc in the Colours window) are added up and allocated to the central convection node (having the unique environmental temperature).

Suppose the air cavity is modelled with colours all of type BC_FREE (only possible with the RADCON module). The radiative heat transfer is calculated taking together all these colours forming one global zone in which all view factors are calculated. The convective heat transfer is calculated with reference to one central convection node (having an unknown air temperature).

This default behaviour can be changed. An air cavity can contain more than 1 convection node by using several colours in that cavity and unlinking those colours. For each unlinked colour and for the remaining block of not unlinked colours in the same air cavity a separate convection temperature will be calculated using separate convective heat balances (based on the one hand on the surface temperatures of the adjacent material surfaces and the corresponding convective heat transfer coefficients, and on the other hand on the convective heat powers related to the colours). The radiative heat balance (in case of BC_FREE cavity) remains unchanged, i.e. considering the global air cavity in which all view factors are determined.

A colour is made unlinked manually by adding per colour (that you want to unlink) a text line at the end of the VOLTRA data file (with extension .vtr) using a text editor (e.g. Windows Notepad). The syntax of this line is:

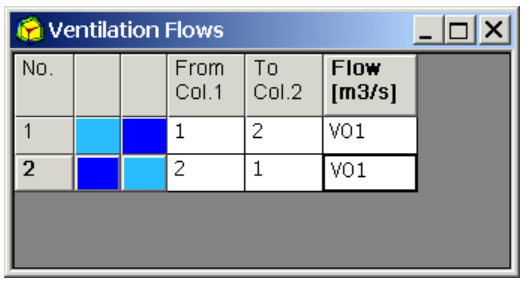
unlk=c

where c = colour number (0..255) for unlinked colour.

When considering ventilation flows through different air zones (cf. section B.10), the air temperatures of these zones are automatically made unlinked.

B.10. Ventilation flows

Ventilation flow paths can be defined in the Ventilation Flows window, opened with *Edit* > *Ventilation Flows*. Add new ventilation flows with the command *Edit* > *Insert After*.



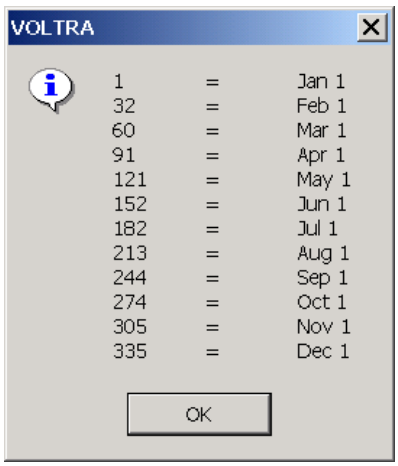
For each ventilation flow definition line a ventilation source and ventilation destination must be entered. Both are identified by colour numbers to the corresponding boundary conditions.
The ventilation source (in the column with header "From Col. 1") can be any type of boundary condition (BC_SIMPL, BC_FRE_S, BC_FREE, BC_SKY or BC_NOSKY). The ventilation destination (in the column with header "To Col. 2") must be a boundary condition of type BC_FRE_S or BC_FREE.
The ventilation flow (last column) is a constant value or a reference to a ventilation function (V##) as defined in the Functions window.
The user should take care that all defined ventilation flows refer to a realistic ventilation scheme. A ventilation path can originate from an outside environment, pass through some internal zones and leave to another outside environment. But a ventilation path can also pass through a closed circuit of only internal zones.

All air cavities of type BC_FRE_S and BC_FREE that occur as ventilation source or ventilation destination in the Ventilation Flows window are automatically unlinked without the need of explicit definition as explained in section B.9.

B.11. Calculation parameters

The Calculation Parameters dialog box is opened with *Edit > Calc Parameters*. Compared to TRISCO some new parameters concerning the time dimension occur:

- Time step: this is the time distance between two successive dynamic system calculations. (About the time format: days, hours, minutes and seconds are separated by colons.)
- Start-up calculation duration: this is the time duration before the actual start of the calculation (where reporting starts) with the purpose to get good dynamic start values.
  The boundary condition values of time-dependent functions are taken before the time origin of those functions, so that the actual calculation (at the end of the start-up calculation duration) starts at time 0. Internal functions which are not periodic (i.e. functions of type STEP0 and STEP1), get the function value at time 0 during the entire start-up calculation duration. Periodic functions are extended for negative time values with the same periodic function course. For external functions the "previous function" is taken, as defined in the function editor FUNCEDIT (cf. Chapter F).
- Calculation duration: duration of the dynamic calculation during which time step results and report items can be saved (e.g. to produce a graphic animation). The calculation start is always at time 0000:00:00:00 (i.e. 0 days, 0 hours, 0 minutes, 0 seconds).
- Day number at start of calculation: number (between 1 and 365) to indicate the day in the year where the calculation starts. This is important when the used (external) function is related to a calendar date: e.g. a test reference year, with hourly climatic data of a typical year in a given location. The start date of the external function may be different from the start date of the calculation.
  The button "i" near the input field gives, when pressed, the day numbers for the first day of each month.

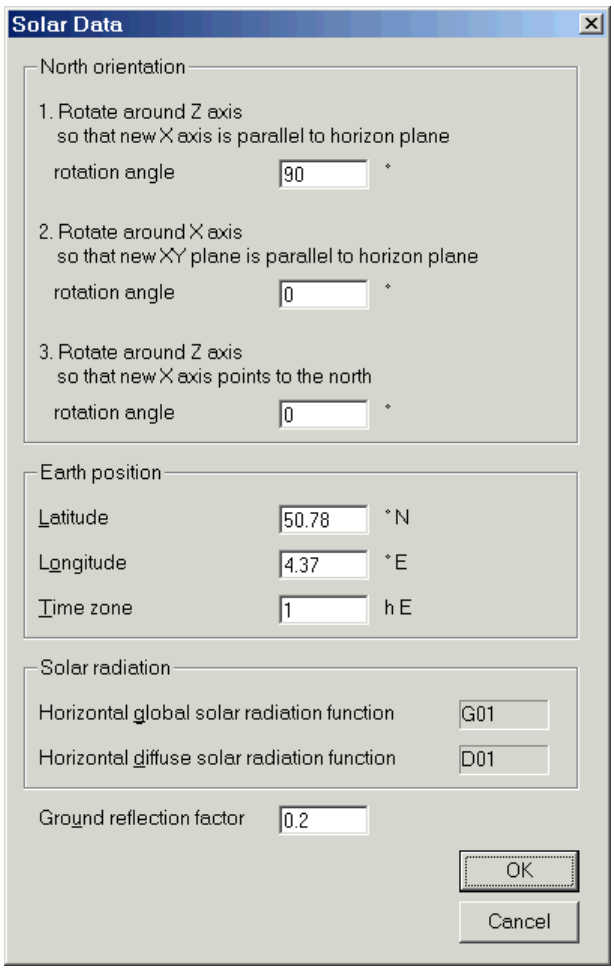


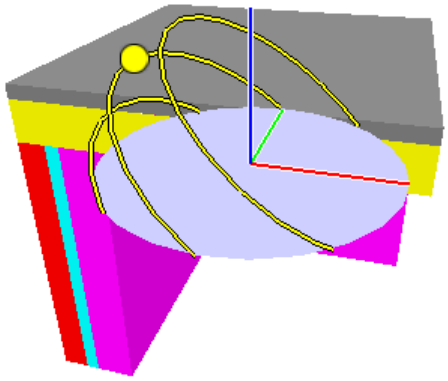
The other calculation parameters in the Calculation Parameters dialog box are valid for each time step calculation, and are explained in the TRISCO manual.
The given number of iteration cycles is only applied for the first time step (i.e. solution of the initial steady-state system, cf. section C.2). If the initial temperature differences are rather high, the number of iteration cycles should also be high (to get reliable start values of temperature dependent thermal properties).
For the next time steps (when no ventilation flows are active) the number of iteration cycles is always automatically reset to 1 (independent of the given number of iteration cycles in the Calculation Parameters dialog box).

B.12. Solar data

When the effect of solar radiation on an object model must be calculated, some additional input parameters must be defined in the Solar Data dialog box (*Edit > Solar Data…*).

The parameters are:
- North orientation: three consecutive rotations define the position of the horizontal coordinate system XYZ, with new XY plane equal to the local horizon plane, new X axis pointing to the north, new Y axis pointing to the west and new Z axis pointing to the zenith.
  - The first rotation is around the Z axis, so that the new X axis is parallel to the local horizon plane.
  - The second rotation is around the X axis, so that the new XY plane is parallel to the local horizon plane (and new Z axis points to the zenith).
  - The third rotation is around the Z axis, so that the new X axis points to the north (and new Y axis points to the west).
- Geographical location: latitude (°N), longitude (°E) and time zone (h E).
  The input fields are disabled when these parameters are present in the climate files (with extension .fsg or .fsd) containing solar radiaton data, defined in the Functions window (G01 and D01). The geographical coordinates are then loaded from the solar radiation climate file (.fsg or .fsd).
- Solar radiation functions: the function reference names of horiziontal direct and diffuse solar radiation functions are always G01 and D01. The solar radiation functions must be defined in the Functions window.
- Ground reflection factor: reflection factor of (horizontal) ground surface around the object model. The reflected solar radiation is projected on the external object surfaces using an isotropic diffuse model.
  The input value must be between 0 and 1. A normal value is 0.2. For very reflective grounds a higher value can be used (e.g. snow: 0.8).



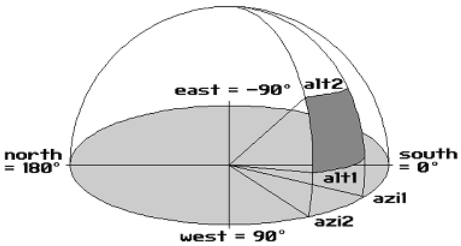


B.13. Show north orientation

Toggle command: *Image > Show North*
Above the object the horizontal plane is shown as a light blue disk (from the top side) or a dark blue disk (from the underside).
The red axis points to the north, the green axis points to the west, the blue axis points to the zenith.
The sun paths are shown for winter solstice (21 December), vernal equinox (20 March) and summer solstice (21 June).
To hide the north orientation, call *Image > Show North* again.

B.14. Sun obstacles

Sun obstacles around the object are defined in the Sun Obstacles window, opened with *Edit > Sun Obstacles*. Each sun obstacle is a spherical rectangle defined by azimuth and altitude coordinates, on the sky hemisphere within which the sun is invisible.
The azimuth and altitude coordinates are defined in the horizontal coordinate system (cf. *Image > Show North*).
Each sun obstacle is defined by four parameters: minimum and maximum azimuth (clockwise angle between –180° and 180°, 0° = south, 90° = west) in the plane of the local horizon (containing the north direction), and minimum and maximum altitude (between 0° at the horizon and 90° at the zenith).



Sun Obstacles

No.	Min. Azimuth [°]	Max. Azimuth [°]	Min. Altitude [°]	Max. Altitude [°]
1	-180	180	0	5

By default one sun obstacle (defined by a zone up to 5° high above the horizon in all directions around) is present for each new VOLTRA file (cf. figure above right).
A new sun obstacle is added using *Edit > Insert Row*.
A sun obstacle is deleted using *Edit > Delete Row*.

B.15. Controls

A control is a method to steer the thermal system, based on a sensor temperature which should follow a time dependent target temperature by heating or cooling, obtained by replacing a boundary condition or material property function (used in the Colours window, Node BCs window, Borderface BCs window, Material BCs window or Ventilation Flows window) with another function (of the same type). In this way e.g. a higher power or ventilation flow can be imposed, to achieve better the goal of the control.
Controls are defined in the Controls window, opened with the command *Edit > Controls*.
A new control can be added with *Edit > Insert Before* or *Edit > Insert After*, and deleted with *Edit > Delete*.

Controls

No.	Sensor node	θ target [T##]	Sens.up [°C]	Sens.dn [°C]	Purpose	Time on [min]	Time off [min]	Function from	Function to	Test Δθ	Δθ [°C]	Zone θ1	Zone θ2
1	2	T02	1.0	1.0	HEATING	10.0	10.0	P01	P02				
2	4	T01	1.0	1.0	COOLING	20.0	20.0	V01	V02	YES	3.0	4	5

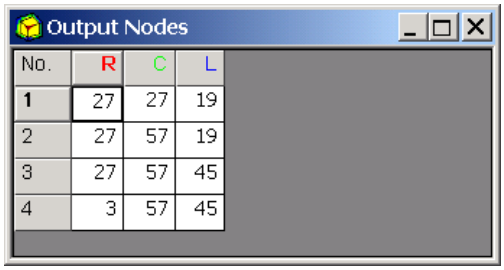
A control is defined by the following elements (corresponding to the different columns):
- Sensor node, where at each calculation time step the temperature is compared to the desired target temperature. The sensor node is defined by the reference number of an output node in the Output Nodes window (cf. section B.16).
- Target temperature: function reference of a temperature function (T01up to T99) defined in the Functions window (cf. section B.3).
- Thermostat sensitivity upward [°C]:
  While a heating control is active, a necessary condition to switch off the control is that the sensor temperature is greater than the target temperature plus the upward sensitivity.
  While a cooling control is not active, a necessary condition to switch on the control is that the sensor temperature is greater than the target temperature plus the upward sensitivity.
- Thermostat sensitivity downward [°C]:
  While a heating control is not active, a necessary condition to switch on the control is that the sensor temperature is less than the target temperature minus the downward sensitivity.
  While a cooling control is active, a necessary condition to switch off the control is that the sensor temperature is less than the target temperature minus the downward sensitivity.
- Purpose: a control can be intended for either heating or cooling.
- Minimum time on: minimum duration that the control must continously remain switched on.
- Minimum time off: minimum duration that the control must continously remain switched off.
- Function from: function reference (E##, H##, I##, M##, P##, R##, S##, T## or V##, with ## = 01 up to 99) to a function defined in the Functions window and referred to in the Colours

window, Node BCs window, Borderface BCs window, Material BCs window or Ventilation Flows window.
The "function from" is valid when the control is switched off.

- Function to: function reference (E##, H##, I##, M##, P##, R##, S##, T## or V##, with ## = 01 up to 99) to a function defined in the Functions window, which must replace the "function from" while the control is switched on.
  The "function from" and "function to" must both be of the same type (i.e. both function references must begin with the same letter).
- Test Δθ: test the temperature difference between two zones (of a ventilation path), which must be greater than a minimum required temperature difference, as (additional) condition to switch on a ventilation control (for which "function from" and "function to" start with the letter V).
- Minimum required temperature difference [°C] between two zones (of a ventilation path).
- Source zone (or zone 1) for temperature difference test, which is defined by its colour number (between 0 and 255) in the Colours window.
- Destination zone (or zone 2) for temperature difference test, which is defined by its colour number (between 0 and 255) in the Colours window.

B.16. Output Nodes

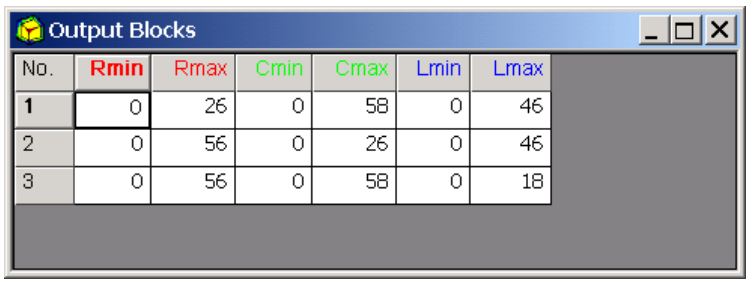
Output nodes are points to which reference is made in a report text output (cf. section E.4) to show the course of temperatures in those points as a function of time.
Output nodes can also be used as sensor points in controls (cf. section B.15).
Output nodes are defined in the Output Nodes window, opened with the command *Edit > Output Nodes*. The definition of an output node consists of a sequence number and the point coordinates (X,Y,Z or R,C,L depending on the active coordinate system). The position of the current output node is represented in the Image window by the intersection of three lines parallel to the coordinate axes (coloured red, green and blue).
Output nodes can be inserted (using *Edit > Insert Before* or *Edit > Insert After*) and deleted (using *Edit > Delete*).



No.	R	C	L
1	27	27	19
2	27	57	19
3	27	57	45
4	3	57	45

B.17. Output Blocks

Output blocks can be used in a report text output (cf. section B.18) to show the course of incoming heat flows (in W) through conduction through the boundary faces of those output blocks. The heat flows by radiation or convection are not taken into account. So only the intersection parts of the boundary faces of an output block with the object material is important.
Output blocks are defined in the Output Blocks window, opened with the command *Edit > Output Blocks*. A new output block can be added using *Edit > Insert Before* or *Edit > Insert After*. The definition of an output block consists of a sequence number and 6 coordinates.



No.	Rmin	Rmax	Cmin	Cmax	Lmin	Lmax
1	0	26	0	58	0	46
2	0	56	0	26	0	46
3	0	56	0	58	0	18

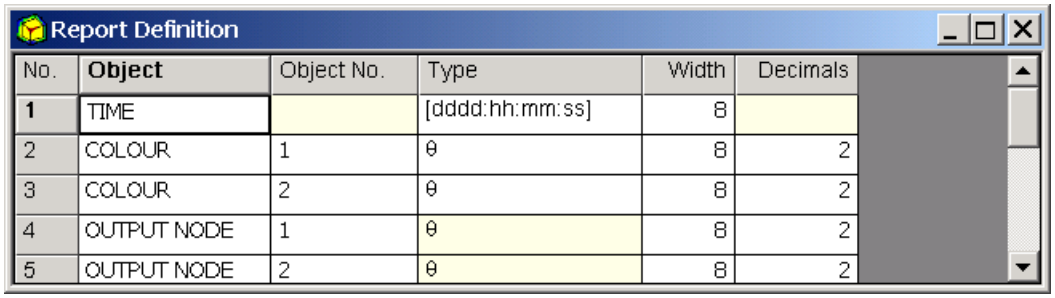
No.	Xmin	Xmax	Ymin	Ymax	Zmin	Zmax
1	-0.5	12.5	-0.5	28.5	-0.5	22.5
2	-0.5	27.5	-0.5	12.5	-0.5	22.5
3	-0.5	27.5	-0.5	28.5	13.5	22.5

The boundary faces of an output block always lie in between the grid coordinates as defined in the Grid window. In this way the boundary faces can be broken down in elementary boundary faces of control volumes around material nodes, through which the energy flows through conduction can easily be calculated.
In the RCL coordinate system the coordinates of output blocks are represented by even numbers (0,2,4,…).
In the XYZ coordinate system an output block coordinate ends with .5 to indicate that its position is halfway between two consecutive grid locations (as defined in the Grid window).
The outline of the current output block is shown in the Image window.
Object clipping (with *Edit* > *Clip Object*) has no effect on the calculation of heat flows into the output blocks; it has only a visual effect in the Image window.

Remarks for users of SECTRA and VOLTRA up to version 2.
1. The concept of output blocks replaces the concepts of line and plane definitions.
2. Line and plane definitions of an old SECTRA or VOLTRA file are skipped when such a file is imported using *File* > *Import Data*….

B.18. Report Definition

The contents of a report in the Text Output window (first select *Output* > *Text Output*, then *View* > *Report Output*) after a calculation has been executed, is determined by the report definition (treated in this section) and the report frequency (cf. section B.19).
The input of the report definition is done in the Report Definition window, opened with the command *Edit* > *Report Definition*.
The report definition consists of several report items, one per line in the Report Definition window.
A new report item is added via *Edit* > *Insert Before* or *Edit* > *Insert After*.
A report item can be deleted using *Edit* > *Delete*.
During the generation of a report in the Text Output window, a report line is written per report step (which equals the calculation time step or a multiple of it, as defined by the report frequency).
The report line consists of the actual values of the report items (separated by tabs) at the current time step.



No.	Object	Object No.	Type	Width	Decimals
1	TIME		[dddd:hh:mm:ss]	8	
2	COLOUR	1	θ	8	2
3	COLOUR	2	θ	8	2
4	OUTPUT NODE	1	θ	8	2
5	OUTPUT NODE	2	θ	8	2

A report item is defined by the following elements (corresponding to the different columns):

- Object: a toggle with values TIME, COLOUR, NODE BC, BORDER BC, MATERIAL BC, OUTPUT NODE, OUTPUT BLOCK, CONTROL, SUN.
- Object Number, which meaning is dependent on the selected object:
  TIME: not applicable.
  COLOUR: colour number (cf. first column in Colours window).
  NODE BC: node boundary condition number (cf. first column in Node BCs window).
  BORDER BC: border face boundary condition number (cf. first column in Borderface BCs window).
  MATERIAL BC: material boundary condition number (cf. first column in Material BCs window).
  OUTPUT NODE: output node number (cf. first column in Output Nodes window).
  OUTPUT BLOCK: output block number (cf. first column in Output Blocks window).
  CONTROL: control number (cf. first column in Controls window).
  SUN: not applicable.
- Type, a toggle with values dependent on the selected object:

TIME	[s]	time in seconds of the current time step
	[dddd:hh:mm:ss]	time in days, hours, minutes and seconds of the current time step
COLOUR	λ_{eq}	equivalent thermal conductivity [W/(m.K)] (for colour of type EQUIMAT)
	θ	boundary condition temperature [°C] (for colour of type BC_SIMPL or BC_FRE_S)
	h	total surface heat transfer coefficient [W/(m^2.K)] (for colour of type BC_SIMPL or BC_FRE_S)
	q	boundary condition heat flux [W/m^2] (for colour of type BC_SIMPL, BC_FRE_S, BC_FREE, BC_SKY or BC_NOSKY)
	θ_a	boundary condition air temperature [°C] (for colour of type BC_FREE, BC_SKY or BC_NOSKY)
	h_c	convective heat transfer coefficient [W/(m^2.K)] (for colour of type BC_FREE, BC_SKY or BC_NOSKY)
	P_c	convective power into air cavity [W] (for colour of type BC_FREE or BC_FRE_S)
	θ_r	boundary condition radiation temperature [°C] (for colour of type BC_SKY)
	Q_{in}	heat flow from boundary condition into object [W] (for colour of type BC_SIMPL, BC_FRE_S, BC_FREE, BC_SKY, BC_NOSKY or TRANSMAT)
	Q_{out}	heat flow out of object into boundary condition [W] (for colour of type BC_SIMPL, BC_FRE_S, BC_FREE, BC_SKY, BC_NOSKY or TRANSMAT)
	qsol Xmin	

(area weighted average) absorbed solar flux on all faces oriented to Xmin (including faces that do not receive any solar radiation) [W/m^2] (for colour of type MATERIAL or EQUIMAT)

qsol Xmax
(area weighted average) absorbed solar flux on all faces oriented to Xmax (including faces that do not receive any solar radiation) [W/m^2] (for colour of type MATERIAL or EQUIMAT)

qsol Ymin
(area weighted average) absorbed solar flux on all faces oriented to Ymin (including faces that do not receive any solar radiation) [W/m^2] (for colour of type MATERIAL or EQUIMAT)

qsol Ymax
(area weighted average) absorbed solar flux on all faces oriented to Ymax (including faces that do not receive any solar radiation) [W/m^2] (for colour of type MATERIAL or EQUIMAT)

qsol Zmin
(area weighted average) absorbed solar flux on all faces oriented to Zmin (including faces that do not receive any solar radiation) [W/m^2] (for colour of type MATERIAL or EQUIMAT)

qsol Zmax
(area weighted average) absorbed solar flux on all faces oriented to Zmax (including faces that do not receive any solar radiation) [W/m^2] (for colour of type MATERIAL or EQUIMAT)

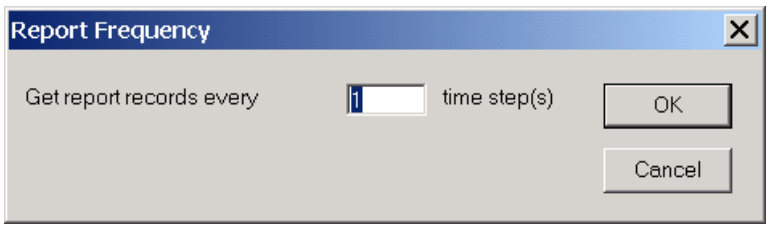
NODE BC	θ	temperature [°C]
	P	power [W]
BORDER BC	θ	temperature [°C]
	q	heat flux [W/m²]
MATERIAL BC	θ	temperature [°C]
	p	power density [W/m^3]
OUTPUT NODE	θ	temperature [°C]
OUTPUT BLOCK	P	heat flow through conduction into output block [W]
CONTROL	ON	control on/off status (0=off, 1=on)
SUN	AZIMUTH	sun azimuth [°] (0:south, 90:west, -90:east)
	ALTITUDE	sun altitude [°] (0:horizon, 90:zenith)

- Width: (minimum) number of characters for formatting the output values in the output report
- Decimals: number of digits after the decimal point, to which the output values are rounded.

If a report item definition is logically impossible, this item is skipped in the output report.

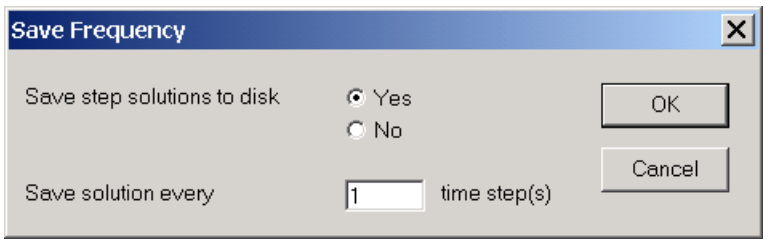
B.19. Report Frequency

A report line in the report output is written for every time step or every fixed number of time steps. This number is set, before the calculation is started, in the Report Frequency dialog box, opened with the command *Calc > Report Frequency…*.
When a calculation is started, the amount of memory is allocated to save the report records during the calculation. At the end of the calculation the report records are all available in memory and can be output in the Text Output window. The report records are lost from memory when the active VOLTRA document is closed.



B.20. Save Frequency

During a calculation intermediate solutions (i.e. the calculated temperatures in all calculation nodes, calculated heat fluxes using RADCON, absorbed solar fluxes) at a fixed number of time steps can be saved to disk to use later in graphic output or text output (to view the solutions at those time steps).
The save frequency must be set, before the calculation is started, in the Save Frequency dialog box, opened with the command *Calc > Save Frequency…*.



The solutions are saved in .sol files, .flx files and .sfx files with the same file name of the .vtr input data file appended with a 4-digit serial number. For example if the input data file is PilotexVoltra.vtr, then the solution files are PilotexVoltra0001.sol, PilotexVoltra0002.sol, PilotexVoltra0003.sol etc.
The format of the .sol and .flx files is identical to that of the TRISCO solution files.

B.21. Importing data

The command *File > Import Data…* allows to create a new VOLTRA data file starting from a BISTRA data file, a BISCO data file, a bitmap or an old VOLTRA & SECTRA data file format. Choose the wanted file type in the File Open dialog box.

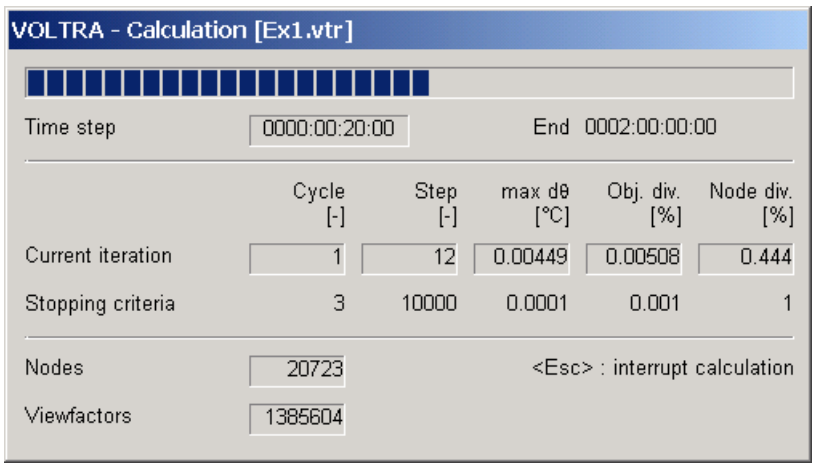
When a BISTRA data file (with extension .bst) is imported, the north orientation must be redefined in VOLTRA (i.e. azimuth and altitude of north direction in the Solar Data dialog box, opened with *Edit > Solar Data…*). Also the report definition must be redefined (*Edit > Report Definition*).

Remarks when importing an old VOLTRA & SECTRA data file (with extension .dat, created using VOLTRA/SECTRA version 1 or 2 in MS-DOS):
- The directory of function files is not known (because directory paths are not read any more from Voltra.prm), although the right file names (without directory) are shown in the Functions window. Install the right directory by editing the function name of external files (press <Enter> or double click on the Filename cell in the Functions window) and selecting the correct file path in the Open dialog box.
- Always check the surface boundary conditions. The surface boundary conditions of old SECTRA data files are not imported, because their definition is not compatible with the definition in the new version.
- Node definitions, line and plane definitions, alphanumeric and graphic output definitions are not imported.

CHAPTER C SYSTEM CALCULATION

C.1. Start calculation

After the input of data is finished, a calculation can be started with the command *Calc* > *Calc System*. First the view factors are calculated (if required, as in TRISCO). During the system calculation a monitor is shown containing the current time step, the iteration parameters (as in TRISCO) for the current time step, the number of system nodes and the number of calculated view factors.
After completion of each time step the Image window is updated showing the temperatures of the last time step. If necessary the temperature range scale can be modified (before the calculation is started) in the Graphic Output window (*Output* > *Graphic Output*) using the command *Settings* > *Temperature Range*….



If there is a start-up calculation requested, first the start-up time steps are shown (from time 0000:00:00:00 up to the total start-up duration). Neither reporting nor solution saving is done during the start-up duration. After finishing the start-up calculation, the normal calculation duration commences. The time steps of the normal calculation duration are shown again starting from time 0000:00:00:00. During the normal calculation, reporting and solution saving are possible.

During the calculation a report file is written, when at least 1 report item is defined in the Report Definition window (cf. section B.18). The content is the same as in the Report output (cf. section E.4). The report file has the same file name as the data file, and has the extension .txt.

A calculation can be interrupted at any time by pressing the <Esc>-key. The calculation results of the last executed time step can be examined in the Graphics Output window and Text Output window. If the "Save step solutions to disk" option is enabled in the Save Frequency dialog box (cf. section B.20), the solution files up to the last calculated time step are present. If a report definition is given (cf. section B.18), the report records up to the last calculated time step can be viewed in the Text Output window.

If a calculation is restarted after it has been interrupted, the calculation restarts from the very beginning without reuse of the already calculated time step solutions.

C.2. Calculation principles

For the first time step (of the start-up calculation duration if requested, else of the normal calculation duration) a steady-state system (as in TRISCO) based on the boundary condition function values evaluated at the initial time is set up and solved. Multiple iteration cycles (as defined as calculation parameter) are used to get good initial temperature dependent properties. If the initial temperature differences of the steady-state system are high, the number of iteration cycles should also be high (so that the temperature dependent thermal properties converge to stable values).
If a start solution (defined as .sol file) should be adopted at the first time step, this solution should be renamed to the fixed file name StartVoltra.sol in the directory of the .vtr input data file.
The start solution is only used if this solution is compatible with the input data (i.e. same number of nodes, same number of object nodes, same number of blocks, same number of node boundary conditions).
Delete the file StartVoltra.sol after the calculation, otherwise it will be reused as start solution (if compatible with the input data) in all following calculations.

For the next time steps the boundary condition function values are updated and the material volume capacity is taken into account. The Cranck-Nicolson finite difference method is used to formulate the energy balance for all control volumes around material nodes. For all other nodes without capacity (e.g. black surface nodes, radiation nodes of a boundary condition) the energy balance at the current time step is formulated.
Only 1 iteration cycle per next time step is considered (except when ventilation flows are treated), even if the calculation parameter "number of iteration cycles" has a higher value. This supposes fluent boundary condition changes (no abrupt discontinuities) during the calculation period.

When the thermal conductivity and/or specific heat of some materials are defined as temperature dependent functions, those properties are adapted before each new iteration cycle (of the steady-state system for the first time step) and each next iteration step based on the obtained temperatures in the previous iteration cycle or previous time step.

CEN-values are recalculated (if required by the corresponding setting in the Calculation Parameters dialog box) before each iteration cycle or time step, and can be reported in the output report (see variables of type λ_{eq} and h_c in the report definition; cf. section B.18), but the initial values in the Colours window are not updated (as opposed to what happens in TRISCO).

C.3. Processing ventilation flows

When ventilation flows are present in the input data, the system matrix is not symmetrical any longer, and therefore each iteration cycle is split in two successive subtasks:

- First the solution of a small subsystem of only convection nodes into which ventilation flows arrive. The number of these ventilation nodes is always less than or equal to the number of colours of type BC_FRE_S or BC_FREE (so ≤ 256). The surface temperatures that affect the convection nodes are considered as fixed boundary condition values (as obtained by the solution of the second subtask).
  The ventilation subsystem has an unsymmetrical system matrix, but has a limited number of unknowns (i.e. the temperatures of the ventilation nodes), and is solved using a direct solution method.
- Second the solution of the ventilation replaced system, i.e. the whole system in which the calculated temperatures of the ventilation nodes are considered as fixed boundary conditions. This system has a symmetrical system matrix, and can be solved using an optimised iterative method.

The calculated surface temperatures adjacent to ventilation zones are taken as fixed boundary condition values in the next ventilation subsystem to solve (cf. first subtask).

In the very first iteration cycle (i.e. of the first time step) no initial values of the surface temperatures are known (as required by the first subtask). Then the complete system is solved without any ventilation flows to get start values for the surface temperatures for the first subtask of the next iteration cycle.

When ventilation flows are present, a variable number of iteration cycles is executed per iteration step independent of the given maximum number of iteration cycles as defined in the Calculation Parameters dialog box. The number of iteration cycles per iteration step is automatically stopped when all temperature differences between the calculated temperatures in the ventilation nodes of the current and previous iteration cycle are smaller than the given maximum temperature difference in the Calculation Parameters dialog box (a typical value is 0.0001°C). However it may be possible (dependent on the input data) that there will be no convergence. For this case the iteration cycles are also stopped when any temperature difference of a ventilation node between the current and previous iteration cycle is greater than 1000000°C. Then the program resets all node temperatures of the whole system to 0°C, so that the user can see the solution of the system has failed, and that he should inspect and alter the input data.

The following error messages may occur when doing a calculation:
- "Syntax error in ventilation flow N":
  The ventilation flow in the Ventilation Flows window at line N contains a syntax error. Either the ventilation source is not a boundary condition (i.e. a colour of type BC_SIMPL, BC_FRE_S, BC_FREE, BC_SKY or BC_NOSKY), or the ventilation destination is not a boundary condition of type BC_FRE_S or BC_FREE.
- "Error in ventilation system":
  The combination of all ventilation flows as defined in the Ventilation Flows window does not correspond to a physically correct ventilation system. This error occurs when the ventilation system has not a unique solution (undetermined system).

C.4. Calculation of solar fluxes

Menu command: *Calc > Calc Solar Fluxes*

This command is enabled when a *solar zone* is present in the input data. This is a colour of type BC_SIMPL or BC_SKY with sun toggle set to YES.

Before executing this command be sure to define a text report (cf. section B.18), the report frequency (cf. section B.19) and/or the save frequency (cf. section B.20), otherwise no results of calculated solar fluxes are saved for text output (cf. section E.4) and/or graphic output (cf. section D.8).

First the view factors are calculated, if not yet present.
It is recommended to calculate first the view factors using a coarser grid, so that the number of view factors will be lower. Simplify the grid, and execute *Calc > Calc View Factors*. Then refine the grid, and start *Calc > Calc Solar Fluxes*. A prompt appears with the question "Recalculate view factors ?". Answer "No". Then it follows that the distribution of diffuse radiation and diffuse reflection will be much faster (cf. section C.9).
Note that the syntax of the created view factor file (with extension .vwf) from VOLTRA v6.0w is modified against the format of the .vwf file of previous versions of VOLTRA.

The solar fluxes are calculated upon all surfaces exposed to the sun. This includes direct solar radiation as well as diffuse solar radiation. Also (direct and diffuse) solar radiation through transparent walls (glazings) is calculated. The calculation process is explained in detail in the next sections (cf. sections C.5 - C.9).

When solar flux records are defined the Report Definition window (e.g. "qsol Xmin") these results are saved in memory every N1 time steps (as defined in the Report Frequency dialog box) of the calculation duration (as defined in the Calculation Parameters dialog box), ready for use in the Text Output window (cf. section E.4).
The absorbed solar fluxes are saved every N2 time steps (as defined in the Save Frequency dialog box) of the calculation duration in the files with extension .sfx. Also a header file with extension .sfd is created. These files are loaded when viewing absorbed solar fluxes in the Graphic Output window (cf. section D.8).

A system calculation (*Calc > Calc System*) includes automatically the solar fluxes calculation, when required. The absorbed solar fluxes on each surface are converted to node powers, which are used as additional boundary conditions of the thermal problem. The absorbed solar flux on a surface node of a transparent material is uniformly distributed over the system nodes on the grid line perpendicular to the surface inside the material (i.e. mass absorption). The conversion to node powers is also further treated in sections C.6 - C.9.

The absorbed solar fluxes on each elementary surface are saved per time step in a file with extension .sfx. Global header information is saved at the start of the calculation in a file with extension .sfd. These files are read from the Text Output window and Graphic Output window when needed.

C.5. Solar processor input data

The solar processor is activated when:
1. A *solar zone* is present: i.e. a colour of type BC_SIMPL or BC_SKY with sun flag activated (defined in Colours window, column "Sun", toggle value set to YES).
2. Solar radiation data are present: both a function G01 and a function D01 must be defined in the Functions window.
   G01 refers to a climate file with extension .fsg, containing the global solar radiation (in W/m^2) on a horizontal surface.
   D01 refers to a climate file with extension .fsd, containing the diffuse solar radiation (in W/m^2) on a horizontal surface.
   The climate files .fsg and .fsd are the same as those used in CAPSOL and BISTRA.
   Climate files are available for different locations in the world (e.g. European Test Reference Years). The function data can be viewed (in the Function Graph window) and edited (using the program Funcedit.exe in the directory …\Physibel\Voltra, see Chapter F).

Input parameters with respect to the solar processor:
- North orientation in the geometric model.
  The position of the horizontal coordinate system (with axes pointing to the north, west and zenith) with respect to the object coordinate system must be defined (*Edit > Solar Data…*, cf. section B.12).
- Geographic position of the object model, defined by north latitude (°N), eastern longitude (°E) and time zone (h E) (*Edit > Solar Data…*, cf. section B.12).
- Ground reflection factor (*Edit > Solar Data…*, cf. section B.12).
- Per material: solar reflection factor (may be dependent on the angle of incidence, defined by a solar reflection factor function in the Functions window) and solar transmission factor (equals 0

for a nontransparent material).
These material properties are defined in the Colours window (last two columns).
A solar reflection factor function is referenced by R##, with ## = 01 to 99, and refers to the Functions window.

- Year day number (between 1 and 365) of the start of a calculation period (*Edit > Calc Parameters…*, cf. section B.11). A calculation period always starts at midnight (= 0 h) of this day, but may be preceded by a pre-calculation period (to get dynamic start values of the node temperatures).
- Sun obstacles: shadow zones defined by angular coordinates in the sky hemisphere (*Edit > Sun Obstacles*, cf. section B.13).

At every time step the solar load on the object model is calculated. The solar load is expressed as a calculated node power per system node. These node powers are used as supplementary boundary conditions of the system besides other boundary conditions (e.g. the external temperature).

C.6. Solar transmission factor in VOLTRA

The solar transmission factor τ in VOLTRA is applied after subtraction of the solar reflection (which can be dependent on the angle of incidence of solar radiation, when a solar reflection function is used).

Normally (out of the scope of VOLTRA) the solar reflection, transmission and absorption are defined for solar radiation at normal incidence (angle of incidence = 0°): ρ_0, τ_0, α_0, with $\rho_0 + \tau_0 + \alpha_0 = 1$.

After subtraction of reflection (as for the input value of τ in VOLTRA): $\tau + \alpha = 1$.

The input value of τ in VOLTRA can be calculated from ρ_0 and τ_0:

$$\tau_0 = (1-\rho_0)\times\tau \quad \text{or} \quad \tau = \frac{\tau_0}{1-\rho_0}.$$

Suppose for an angle of incidence of e.g. 30° that the solar reflection factor ρ_{30} is known from a solar reflection function as defined in the Functions window.
Then the actual solar transmission factor τ_{30} and solar absorption factor α_{30} can be calculated from the constant value of τ as input in VOLTRA:

$$\tau_{30} = (1-\rho_{30})\times\tau$$

$$\alpha_{30} = (1-\rho_{30})\times(1-\tau) \quad \text{or} \quad \alpha_{30} = 1-\rho_{30}-\tau_{30}$$

C.7. Solar load to external surfaces

An *external surface* is a surface of an object (with colour type MATERIAL) in direct contact with a *solar zone* (colour type BC_SIMPL or BC_SKY, and sun flag set in the Colours window).

The *position of the sun* is calculated out of the time of the current time step (day of year, clock time) and the geographical location (latitude, longitude, time zone). Summer time is not taken into account. The position of the sun is located by two angular measures: azimuth (horizontal clockwise angle between the sun position and south) and altitude (angle between the sun position and the horizon). The azimuth of the sun at a fixed clock time may differ for different days of the year due to the irregular movement of the sun (defined by the equation of time): e.g. the azimuth at 12 a.m. solar mean time fluctuates around 0° (= south direction).

For the current time step the actual *global solar radiation* and *diffuse solar radiation* (in W/m^2) *on a horizontal surface* are derived from the corresponding climate data files. Normally these climate files contain hourly values. The current values are derived through linear interpolation from the closest hourly values. For the first and last daylight hour of the day, the (estimated) times of sunrise and sunset are considered.
The user should verify the precise definition of the hourly values in the solar radiation climate data files. Just after sunrise or just before sunset the global (and diffuse) solar radiation should be small enough. We found that the files UCL.FSG and UCL.FSD, derived from the European Test Reference Year (weather data set for computer simulations of solar energy systems and energy consumption in buildings) for Uccle (Brussels, Belgium), issued by the Commission of the European Communities in 1985, should be corrected. The new files UCL_C1.FTE, UCL_C1.FSG and UCL_C1.FSD are based on solar mean time values.

For each external surface the angular position against the north direction is computed: orientation (compass direction) and tilt (height above horizon). From the global and diffuse solar radiation on a horizontal surface, the direct and diffuse *solar irradiation on the area around each node* of the external surface is calculated. A partition of the surface area is made into elementary areas around the nodes on the surface (defined by the calculation grid, as input in the Grid window). The elementary areas are separated by the perpendicular bisectors of the line segments between the node and its neighbouring nodes.
The *direct solar irradiation* is derived from the direct solar radiation on a horizontal surface and the position of the sun. If the sun is not hidden by any sun obstacle (as defined in the Sun Obstacles window), a test ray from the surface node towards the sun is inspected on possible intersections with other (non-transparent) object surfaces. When there are no intersections, the node is sunlit. Otherwise the node is shaded and the direct solar irradiation on the area around the node is cancelled.

The estimation of the *diffuse solar irradiation* on the area around the node of the external surface is more complex.
First the *sky visibility* from the elementary area around the node is used as reduction factor of the diffuse radiation. The sky visibility is calculated using 10000 test rays from the node with random direction on the hemisphere above horizon. For all directions at the front side of the surface, the sky visibility is estimated as the fraction of the test rays not shaded by any sun obstacle or other (non-transparent) object. This is a good estimation of the view factor to the open sky from the elementary area around the node.
Secondly the diffuse radiation depends on the *tilt* of the surface.
In an isotropic diffuse model the diffuse radiation on a sloped surface is proportional to the square of the cosine of half the tilt angle. E.g. the diffuse radiation on a vertical surface is half the diffuse radiation on a horizontal surface (i.e. the surface only sees half of the sky dome).
We use the more correct anisotropic diffuse model developed by Muneer[1], which also distinguishes between shaded and sunlit surfaces and between overcast and non-overcast conditions of the sunlit surfaces. The required parameters can be derived from sun position, slope, orientation, day of year, sunlit status, sky visibility, global and diffuse solar radiation data on a horizontal surface.
Finally *radiation reflected from the ground* in front of the surface, must be added. This radiation is assumed isotropic, and is a function of the global solar radiation on a horizontal surface, the tilt of the surface, and the ground reflection factor, which is an input parameter in the Solar Data dialog box (normal value = 0.2). The ground reflected radiation on a vertical surface is half the ground reflected radiation on a horizontal downward surface.

[1] Muneer T., Algorithms for estimating hourly solar irradiation on slopes, Building Serv. Eng. Res. Technol. 10(2), p. 81-83 (1989)

Now we return to the direct radiation incident on the surface. If the reflection factor of the surface is angle dependent (cf. definition of the material colour in the Colours window), then this factor is determined through interpolation between the values in the solar reflection function file for the actual angle of incidence (angle between direct solar radiation and surface normal). If the solar zone is of type BC_SIMPL, then the reflected direct solar radiation from an external surface is further ignored. If the solar zone is of type BC_SKY, this reflected solar radiation is further processed as diffuse solar radiation (cf. section C.9).
The reflection factor for diffuse radiation is the weighted mean value of the reflection factors for all possible angles of incidence. If the solar zone is of type BC_SIMPL, then the reflected diffuse solar radiation from an external surface is ignored. If the solar zone is of type BC_SKY, this reflected solar radiation is further processed as diffuse solar radiation (cf. section C.9).

After reflection some part of the solar radiation may be transmitted to internal zones (when the solar transmission factor of the surface material, as defined in the Colours window, is greater than 0). The remainder of the solar radiation is absorbed. For an opaque surface (solar transmission factor equals 0) the absorbed solar radiation is converted to node powers in the surface nodes.
For a transparent surface (solar transmission factor greater than 0) the absorbed solar radiation is uniformly distributed (proportionally to the mesh distances) along the grid line through the surface node and perpendicular to the external surface (up to this grid line reaches an opposite material surface or a non-transparent material). This means that all nodes of the (transparent) wall behind a transparent surface node are assumed to have equivalent mass absorption. Only the solar transmission factor of the wall surface in contact to the solar zone is considered.

C.8. Solar load to internal surfaces

The transmitted solar radiation of the radiation on an elementary area of a material surface around a surface node is first transferred to the elementary material surface area at the other side of the wall behind the surface wall. The wall is considered along the grid line through the original surface node, that is perpendicular to the surface, until the opposite surface is reached (that borders the boundary condition at the other side). This wall may consist of different materials (colours of type MATERIAL or EQUIMAT) having different material properties. In fact the transmission factor of a material surface (as input in the Colours window) is the transmittance (after deduction of reflectance) of the wall behind the surface. This means that the given transmission factor is not a pure material property, but it is the combined result of the transmission factors of all materials behind the surface of the given material (i.e. a wall property).
The program VOLTRA requires (for logical results) that when the transmission factor of a material is greater than zero, also the transmission factor of the material at the other side of the wall in the object geometry is greater than zero.

When the zone at the other side of the wall has a colour of type BC_FREE, TRANSMAT, BC_SKY or BC_NOSKY (which requires the RADCON module), then that zone is an *internal zone*, through which the solar radiation is further propagated. The material surfaces bordering an internal zone are *internal surfaces*.
A zone of type BC_FREE has view factor based radiation, and convection with a balanced unknown air temperature. This type is normally used for rooms or larger air cavities.
A zone of type TRANSMAT has view factor based radiation, and conduction using a given thermal conductivity (of still air or another gas). This type is normally used for smaller cavities, e.g. the cavity of a double glazing.

In general a view factor grid should be used that is less detailed (i.e. with a smaller number of wider meshes) than the calculation grid. The view factors in the calculation grid are derived from the view factors in the view factor grid through scaling with the areas of the elementary surfaces. The

precision is nearly the same, but the calculation speed can be enormously improved. This is especially true, because we will see (cf. section C.9) that every time step a linear system of equations must be solved in which the number of unknowns equals the number of view factor surfaces (of the view factor grid).
From VOLTRA v6.0w the format of the view factor file (with extension .vwf) is modified compared to the previous versions.

The transmitted *direct solar radiation* in a node of an internal surface is projected along the direction of direct sun light upon the closest internal surface (of the same internal zone opposite to the emitter internal surface). The power of the transmitted direct solar radiation corresponding to the elementary grid surface around the emitter node is attributed to the elementary grid surface containing the intersection point of the projected solar beam. When this power would cause a flux (i.e. power divided by area) that is greater than the solar radiation on an external surface with the same orientation, then this power is widerly spread over adjacent elementary grid surfaces with the same orientation. This smoothing occurs when the area of the receiver surface is (much) smaller than the area of the emitter surface. Therefore it is recommended to use a (more or less) equidistant grid.
The direct solar radiation through transparent materials (e.g. window glass) causes a sunlit spot on the internal surfaces of an internal zone. This spot will be sharper when the calculation grid is finer.
Part of the incident direct solar radiation on an internal surface is reflected, using the reflection factor of the surface material colour (defined in the Colours window). This reflection factor may be dependent on the angle of incidence (when the reflection factor is defined by a reflection factor function). The reflected radiation is assumed to be diffuse, and will be treated further (cf. section C.9).
The remainder of the incident direct solar radiation on the internal surface is transmitted (when the transmission factor of the surface material colour is greater than zero, as defined in the Colours window) and absorbed. The transmitted and absorbed radiation are treated in the same way as transmitted and absorbed direct solar radiation on an external surface.

The transmitted *diffuse solar radiation* of an elementary grid surface (of an internal surface) is projected upon the other elementary grid surfaces (of the same internal zone) proportional to the view factors from the emitter surface to the receiver surfaces.
Part of the incident diffuse solar radiation on an internal surface is reflected, using the reflection factor for diffuse radiation (which is the mean value of the reflection factors for direct radiation for all possible angles of incidence). The reflected diffuse radiation is treated further (cf. section C.9).
The remainder of the incident diffuse solar radiation on an internal surface is transmitted and absorbed analogously to transmitted and absorbed diffuse solar radiation on an external surface.

C.9. Processing of diffuse solar reflection

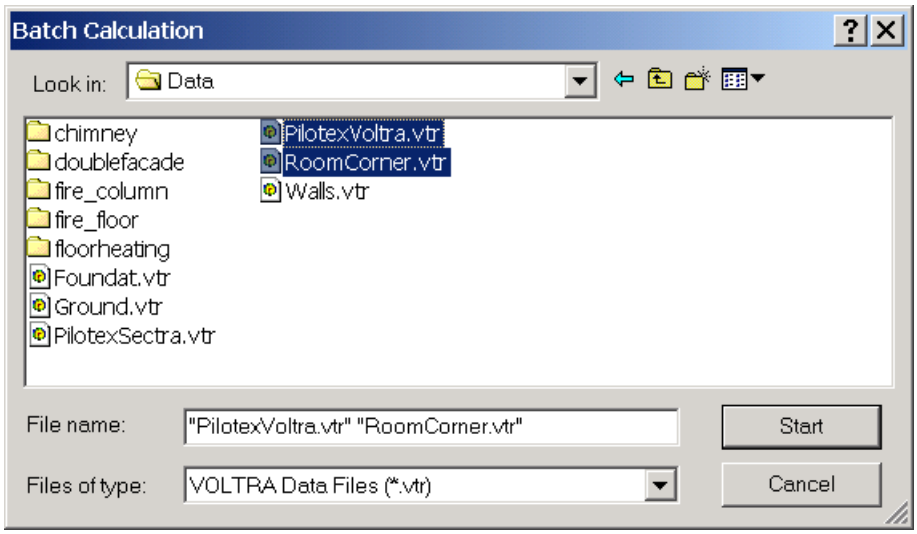
The reflected radiation (originating from either direct or diffuse solar radiation) is always diffuse and causes additional radiation upon all surfaces, that is again reflected, transmitted and absorbed. The final contributions of additional absorption on all internal surfaces are calculated using the radiosity method based on the view factor grid.
The radiosity of each elementary surface of the view factor grid equals the amount of energy that is given off. The energy incident on the surface (which we consider as unknown of the system) equals the sum of all reflected and transmitted energy from other surfaces, multiplied by the view factors from those surfaces to the first surface. The reflected energy from another surface equals the energy incident on that surface (which is an unknown of the system) multiplied by the (diffuse) reflection factor plus the known reflected energy (at the initial state of the radiosity system). The transmitted energy equals the energy incident on the opposite side of the wall (which is an unknown of the system) multiplied by the transmission factor at that side. The transmission factor must first

be corrected for the reflection at that side (because the transmission factor in VOLTRA is defined after subtraction of reflection). Finally this leads to a set of linear equations.
The radiosity method implies that every time step a supplementary linear system of equations must be formulated and solved with the number of unknowns equal to the number of view factor surfaces of the view factor grid. This system is global for the solar zone and all internal zones, because these zones may be linked with one another via transparent walls.

C.10. Batch calculation

The user can launch a batch calculation for several data files (with extension .vtr) in the same folder. The calculations are executed one after the other without any intervention of the user.
To start a batch calculation call the command *File > Batch Calculation…*, select the data files in the Batch Calculation dialog box (hold down the <Ctrl>-key to select more than one file) and press the Start button. It is not possible to select several data files located in different directories.

Per data file a report file is written to disk, containing the output report corresponding to the report definition of the data file (cf. sections B.18, B.19 and E.4). The report file has the same file name as the data file, and has the extension .txt.
When graphic output (i.e. snapshots at given time points and/or animation files of given time periods) is wanted afterwards, the data file should specify that step solutions must be saved to disk (cf. section B.20 and Chapter D).



C.11. Command line program execution

VOLTRA can be run from another application with a data file path (including directory and file extension .vtr) as parameter.
Then no further user action is required. The program starts and ends automatically, and the output is a report file and/or a series of graphic snapshots (as in a batch calculation, cf. section C.10).
The switch "/Automation" is required to activate the batch calculation.

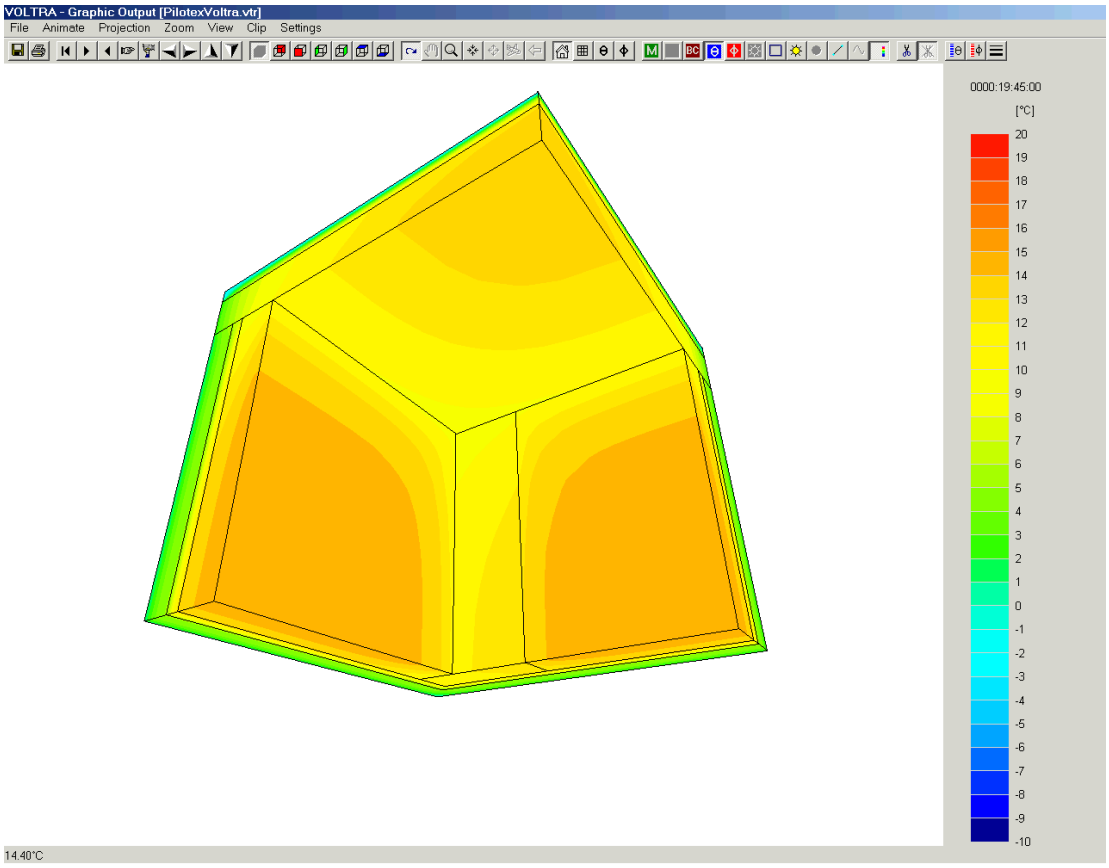
Example of command line launch:

Run >
"c:\…\Physibel\Voltra\Voltra.exe" "c:\…\Physibel\Voltra\Data\PilotexVoltra.vtr" /Automation

CHAPTER D GRAPHIC OUTPUT

D.1. Graphic Output window

The Graphic Output window (which covers the complete VOLTRA application window) is opened with the command *Output > Graphic Output*.
To return to the main VOLTRA window, choose the command *File > Exit*.
The <Esc>-key is reserved here for stopping the current view visualisation or stopping animation functions (cf. section D.2).

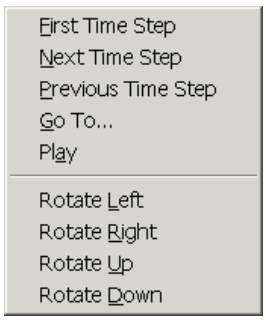


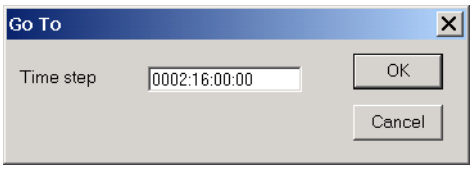
The material colour, boundary condition colour, temperature or heat flux (dependent on the current view option) under the mouse cursor point is shown in the status bar at the bottom of the Graphic Output window.

D.2. Animation functions

The animation functions are available through the Animate submenu.

First Time Step	Go to time 0000:00:00:00 and load the first solution file.
Next Time Step	Go to the next time step and load the next solution file.
Previous Time Step	Go to the previous time step and load the previous solution file.





Go To…	Go to the time step entered by the user and load the corresponding solution file.
Play	Shows successively all solution files starting from the current time step. After the last solution the files are replayed continuously from the first solution. The playing can be stopped by pressing the <Esc>-key.

The next functions do not change the current time step:

Rotate Left	Continuously rotate left around the object.
Rotate Right	Continuously rotate right around the object.
Rotate Up	Continuously rotate upwards around the object.
Rotate Down	Continuously rotate downwards around the object.

All rotation animations move in steps of 5° and can be stopped by pressing the <Esc>-key.
The relative movement of viewpoint and object is directed by the current drag mode (*Settings > Drag Mode…*).

D.3. Save animation images

Menu command: *File > Save Animation Images…*
A sequence of all animation images (as a result of the command *Animate > Play*) can be saved on disk as separate .png or .bmp files.

A Save As dialog box is opened to prompt for a file name.
The file type (PNG or BMP), image size of saved bitmap and font size of legend text are defined via *Settings > Image Size…*.

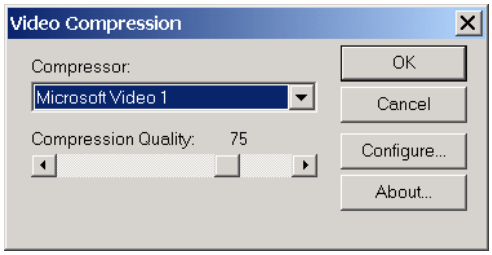
The solution files are loaded consecutively (started with the first solution at time 0000:00:00:00), shown in the Graphics Output window and saved as bitmap. A 4 digit number (starting from 0000) is appended to the chosen file name to generate the different bitmap files.
Saving animation images can be interrupted by pressing the <Esc>-key.

D.4. Write an .avi file

Menu command: *File > Write AVI File…*
Instead of creating a series of animation bitmap files, you can create a single compressed .avi file ("audio-video interleaved" file) to store an animation on disk. An .avi file can be played with e.g. Windows Media Player.

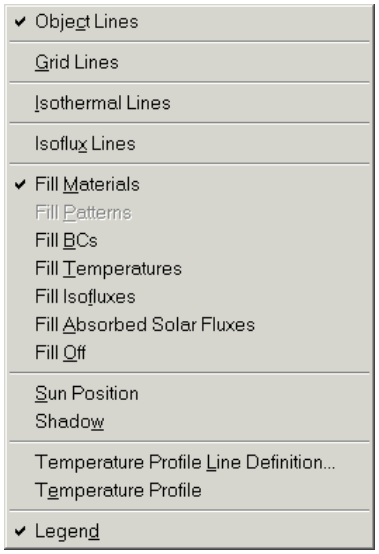
First a Save As dialog box is opened to prompt for a file name.
The bitmap size and font size (for text in the legend) are defined via *Settings > Image Size…*.
Then the first solution is loaded on the screen.
The frame rate must be entered (Write AVI File dialog box) and the video compression (Video Compression dialog box). Choose "Microsoft Video 1" as compressor.

Now all solution files are loaded consecutively and the .avi file is written.



In all images of an animation the legend at the right border is always present (because each frame picture must contain all available colours, which is valid when the legend bar is visible).

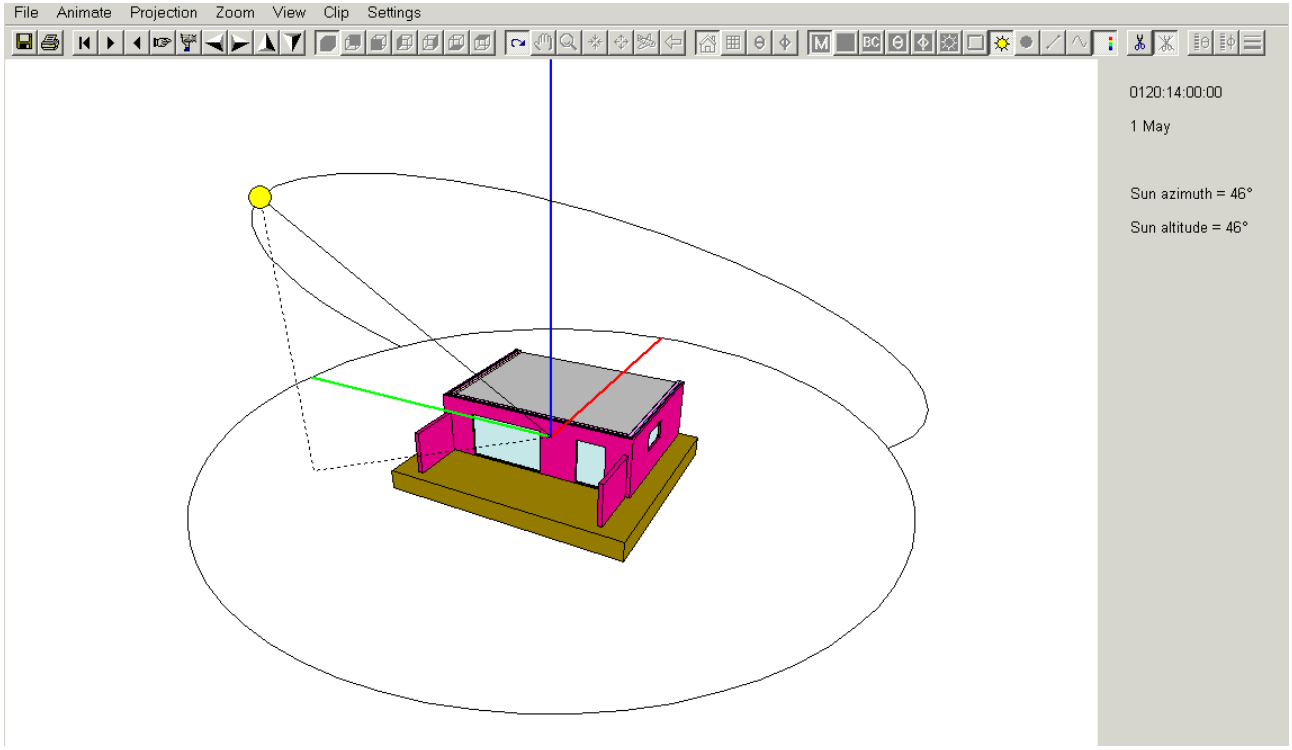
D.5. View submenu



Remark
For the checked view options in the figure above of the View submenu (i.e. *View > Fill Materials* and *View > Legend*) the legend shows the thermal conductivities of the different materials. If those thermal conductivities are defined by temperature dependent functions, the shown values in the legend are taken at 10°C.

D.6. Sun position

The command *View > Sun Position* shows the sun position at the current time step (yellow if visible, or gray if hidden by sun obstacles), the horizon circle, the horizon coordinate system (north, west, zenith directions as resp. red, green, blue lines) and the sun path of the current day. The legend shows the calculation time step, date, sun azimuth (horizontal angle from the south positive to the west) and sun altitude (vertical angle above the horizon plane).



The object is always shown in total zoom (i.e. zooming in is disabled).
The animation functions (*Animate > Play* and *File > Write AVI File…*) allow to view the sun path (sun position changing with time). The time step used is the calculation time step (as defined in *Edit > Calc Parameters…* from the main menu).
All other view commands are disabled until you choose the toggle command *View > Sun Position* again (which quits the sun position view).

The parameters that define the sun position are:
- North orientation (*Edit > Solar Data…*).
- Geographic position (*Edit > Solar Data…*).
- Day of year at start of calculation (*Edit > Calculation Parameters…*).
- Time setting (*Animate > Go To…*).
  The start of calculation corresponds with time 0000:00:00:00.

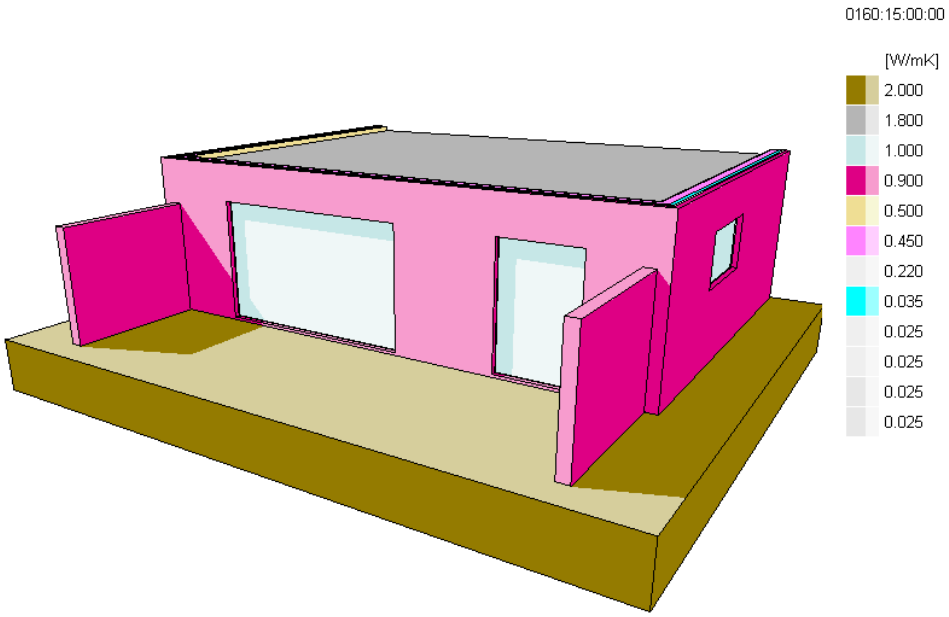
D.7. Sun shaded image

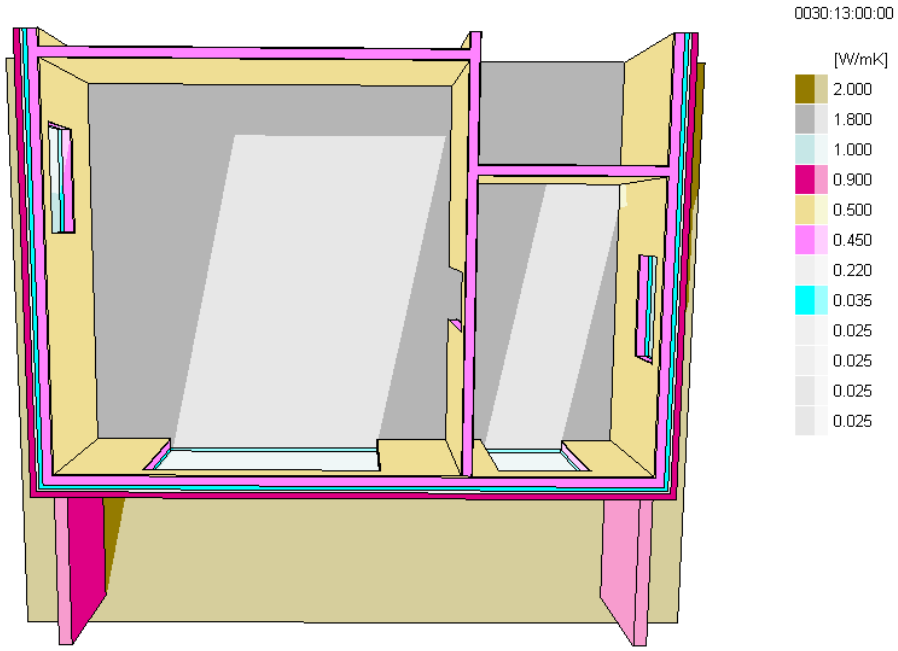
When the sun is present in the object model (which requires the presence of a *solar zone*, i.e. a colour of type BC_SIMPL or BC_SKY with sun input parameter set), a sun shaded image can be generated.

Menu command: *View > Shadow*

A sun shaded image can be generated before the system calculation is done.
Sun obstacles (as defined in the Sun Obstacles window) are ignored.

Sunlit surfaces are shown on external surfaces bordering a solar zone, and on material surfaces of internal zones through transparent walls. If wanted, the object may be clipped, using *Edit > Clip Object* (as in the second figure below, which is a top view with the ceiling clipped off).





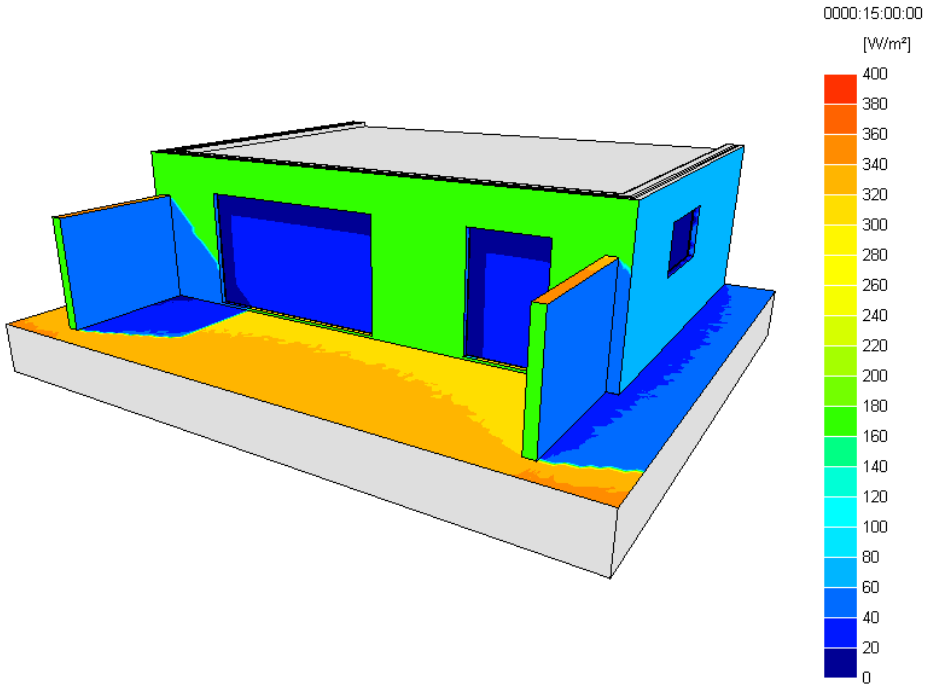
An animation with sun shaded images can be made using *Animate > Play* or *File > Write AVI File…*. The time step defined in the Calculation Parameters dialog box (*Edit > Calculation Parameters…*) is used as animation time step.

D.8. View absorbed solar fluxes

Menu command: *View > Fill Absorbed Solar Fluxes*

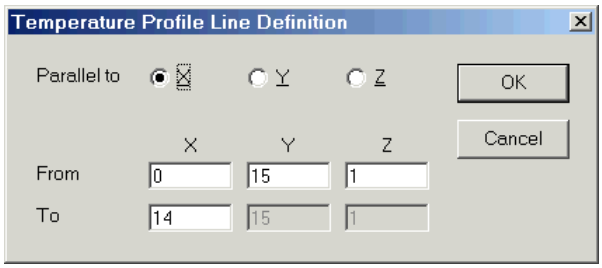
When the solar fluxes are calculated (i.e. after *Calc > Calc Solar Fluxes* or *Calc > Calc System*) and the calculation step solutions (.sfd and .sfx files) are saved on disk (cf. setting in *Calc > Save Frequency…*), this option allows to visualise the absorbed solar fluxes on the object surfaces.

These absorbed solar fluxes are converted to node powers, which are the boundary conditions due to solar radiation, that are used in the system calculation.
For transparent surfaces the total absorbed solar flux is shown, before subdividing the absorbed solar power into node powers within the wall behind the transparent surface (cf. section C.7, last paragraph).
The flux scale can be set via *Settings* > *Heat Flux Range…*.



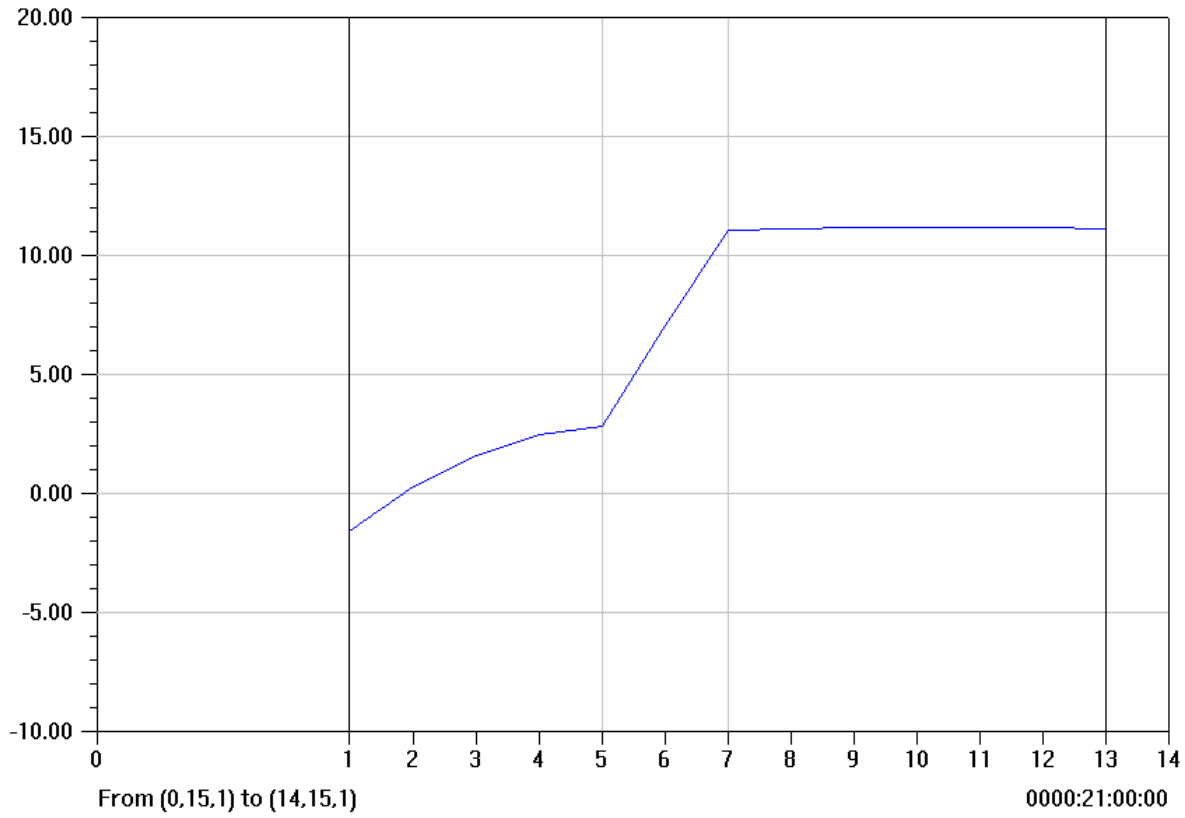
D.9. Temperature profile along a grid line

For any user defined grid line a temperature graph through the intersected material layers can be drawn per calculation time step.
First the desired grid line must be defined using the command *View* > *Temperature Profile Line Definition…*



In the dialog box choose the grid line direction:
– X, Y or Z (in the XYZ coordinate system), or
– R, C or L (in the RCL coordinate system).
Then define the grid coordinates of the starting node (“from”) and ending node (“to”) of the line.

The toggle command *View* > *Temperature Profile* shows the temperature graph.

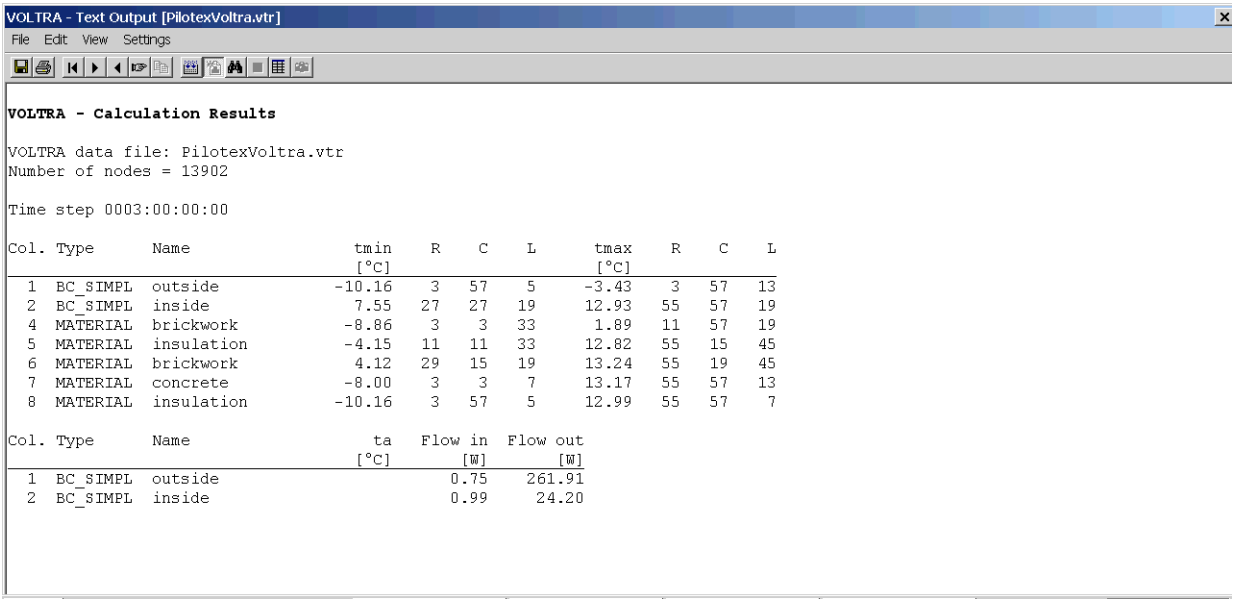


The horizontal axis shows the grid coordinates along the chosen grid direction.
The current calculation time step is displayed at the bottom right (and can be modified, e.g. using *Animate* > *Go To…*).
The vertical axis shows the temperature scale (conform to the settings in *Settings* > *Temperature Range…*).
The blue function line corresponds to the temperature solution at the current time step.
Except the animation functions all other menu commands are disabled until the temperature profile is removed by pressing the toggle command *View* > *Temperature Profile* again.

CHAPTER E TEXT OUTPUT

E.1. Text Output window

The Text Output window (which covers the complete VOLTRA application window) is opened with the command *Output > Text Output*.
To return to the main VOLTRA window, press the <Esc>-key or choose the command *File > Exit*.



Text in the Text Output window is limited to 200 000 characters, which corresponds to 2500 lines of 80 characters.

E.2. Input data

The input data is shown in the Text Output window using the command *View > Input Data*.
Below is a print-out for the example PilotexVoltra.vtr.

VOLTRA - Input Data

```
 Pilot example of the VOLTRA manual
 Three-dimensional corner of a room


VOLTRA data file: PilotexVoltra.vtr

GRID
Grid unit = 0.01 m
```

No.	R	C	L
1-3	10.000	10.000	10.000
3-5	2.500	2.500	2.500
5-7	2.500	2.500	2.500
7-9	2.500	2.500	2.500
9-11	2.500	2.500	2.500
11-13	2.500	2.500	2.500
13-15	2.500	2.500	2.500
15-17	2.500	2.500	2.500
17-19	2.500	2.500	2.500
19-21	2.500	2.500	2.500
21-23	2.500	2.500	2.500
23-25	2.500	2.500	2.500
25-27	2.500	2.500	2.500
27-29	2.500	2.500	5.000
29-31	2.500	2.500	5.000

31-33	5.000	2.500	10.000
33-35	5.000	2.500	10.000
35-37	5.000	5.000	10.000
37-39	5.000	5.000	10.000
39-41	5.000	5.000	10.000
41-43	5.000	5.000	10.000
43-45	5.000	5.000	20.000
45-47	10.000	5.000	
47-49	10.000	10.000	
49-51	10.000	10.000	
51-53	10.000	10.000	
53-55	20.000	10.000	
55-57		20.000	
Sum	140.000	140.000	130.000

BLOCKS

No.	Col.	Rmin	Rmax	Cmin	Cmax	Lmin	Lmax
1	1	1	55	1	57	1	45
2	4	3	55	3	57	19	45
3	5	11	55	11	57	19	45
4	6	15	55	15	57	19	45
5	7	15	27	15	43	19	45
6	2	27	55	27	57	19	45
7	8	3	55	3	57	3	7
8	7	3	55	3	57	7	19

No.	Col.	Rmin	Rmax	Cmin	Cmax	Lmin	Lmax
1	1	0.000	140.000	0.000	140.000	0.000	130.000
2	4	10.000	140.000	10.000	140.000	0.000	100.000
3	5	20.000	140.000	20.000	140.000	0.000	100.000
4	6	25.000	140.000	25.000	140.000	0.000	100.000
5	7	25.000	40.000	25.000	70.000	0.000	100.000
6	2	40.000	140.000	40.000	140.000	0.000	100.000
7	8	10.000	140.000	10.000	140.000	115.000	120.000
8	7	10.000	140.000	10.000	140.000	100.000	115.000

FUNCTIONS
T01: SINE
  Mean value = 0°C
  Amplitudo = 10°C
  Period = 1440 min
  Offset = 420 min
T02: STEP2
  Level 1 = 20°C
  Level 2 = 10°C
  Period = 1440 min
  Duration level 1 = 720 min
  Transition = 60 min
  Start level 1 = 420 min

COLOURS

Col.	Type	CEN-rule	Name	lambda [W/mK]	eps [-]	rho [kg/m3]	c [J/kgK]	t [°C]	h [W/m²K]	q [W/m²]
1	BC_SIMPL	NIHIL	outside					T01	25.00	0
2	BC_SIMPL	NIHIL	inside					T02	5.00	0
4	MATERIAL		brickwork	1.000		1750.0	840.0			
5	MATERIAL		insulation	0.035		40.0	840.0			
6	MATERIAL		brickwork	0.700		1400.0	840.0			
7	MATERIAL		concrete	2.500		2200.0	840.0			
8	MATERIAL		insulation	0.030		40.0	840.0			

Col.	ta [°C]	hc [W/m²K]	Pc [W]	tr [°C]	C1 [-]	C2 [-]	C3 [-]	Sun	rs [-]	ts [-]
1								NO		
2								NO		
4									0.10	0.00
5									0.10	0.00
6									0.10	0.00
7									0.10	0.00
8									0.10	0.00

OUTPUT NODES

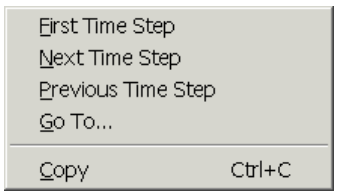
No.	R	C	L
1	27	27	19
2	27	57	19
3	27	57	45
4	3	57	45

Calculation parameters
Time step interval = 0000:00:15:00

```
Start-up calculation duration = 0000:00:00:00
Calculation duration = 0003:00:00:00
Day number at start of calculation = 1
Maximum number of iterations = 10000
Maximum temperature difference = 0.0001°C
Heat flow divergence for total object = 0.001 %
Heat flow divergence for worst node = 1 %
```

E.3. Time step results

Calculation results for a specific time step are shown using the commands *View > Time Step Results*, *View > Corner Nodes* and *View > Node BC's*. These commands are also present in TRISCO. The time step can be set using one of the first four commands in the Edit submenu, which are analogous to the corresponding commands of the Animate submenu in the Graphic Output window (cf. section D.2).



The *Edit > Copy* function allows to copy a selected text part in the Text Output window into the Windows Clipboard, to use it in another program.

Below is a print-out of the *View > Time Step Results* command for the example PilotexVoltra.vtr at time 0002:16:00:00 (set with the command *Edit > Go To…*).

VOLTRA - Calculation Results

VOLTRA data file: PilotexVoltra.vtr
Number of nodes = 13902

Time step 0002:16:00:00

Col.	Type	Name	tmin [°C]	R	C	L	tmax [°C]	R	C	L
1	BC_SIMPL	outside	7.00	3	3	5	7.87	3	57	15
2	BC_SIMPL	inside	8.69	27	27	19	16.06	55	27	45
4	MATERIAL	brickwork	7.47	3	3	23	8.36	11	13	45
5	MATERIAL	insulation	7.52	27	13	19	13.42	55	15	45
6	MATERIAL	brickwork	7.55	27	15	19	16.06	55	27	45
7	MATERIAL	concrete	7.32	23	19	7	14.91	55	57	19
8	MATERIAL	insulation	7.00	3	3	5	14.02	55	57	7

Col.	Type	Name	ta [°C]	Flow in [W]	Flow out [W]
1	BC_SIMPL	outside		0.06	52.51
2	BC_SIMPL	inside		86.97	0.00

Below is a print-out of the *View > Corner Nodes* command for the example PilotexVoltra.vtr at time 0002:16:00:00.

VOLTRA - Temperatures in corner nodes

VOLTRA data file: PilotexVoltra.vtr
Number of nodes = 13902

Time step 0002:16:00:00

R	C	L	t [°C]
3	3	3	7.09
3	3	45	7.50
3	57	3	7.08
3	57	45	7.73
27	27	19	8.69

```
  27    27    45     13.07
  27    57    19     10.90
  27    57    45     16.05
  55     3     3      7.08
  55     3    45      7.73
  55    27    19     10.90
  55    27    45     16.06
  55    57     3      7.25
  55    57    19     14.91
```

E.4. Report output

For the items defined in the Report Definition (cf. section B.18) a report can be output with records at a given frequency of time steps (cf. section B.19). The command *View > Report Output* shows the contents of the .txt file written during the calculation (up to maximum 200 000 characters). Per report time step one line of report values is written. The report values are separated with tab characters (which is useful for export to Microsoft Excel). Each column in the table corresponds to a report item. The meaning of the columns is explained in the header. If a report item is logically impossible, it is skipped.

Be careful with absorbed solar flux results (qsol Xmin, …, qsol Zmax). Area weighted average results are shown for the areas of a material colour oriented to a given direction. Also the areas having the desired orientation, but not bordering a zone in which solar radiation is distributed (i.e. for which qsol = 0 W/m^2), are included in the average value (so the shown result will be lower than what is expected). A possible solution is to split the material blocks into several blocks having different colours (with the same material properties).

Below is a print-out for the example PilotexVoltra.vtr.

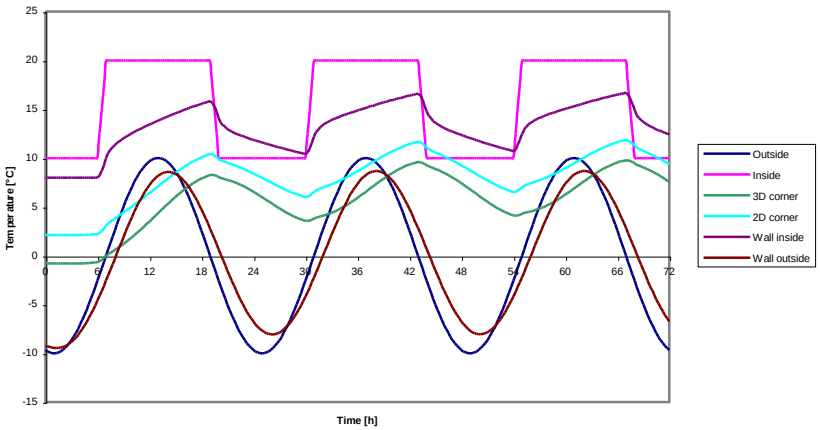
```
VOLTRA - Report Output

VOLTRA data file: PilotexVoltra.vtr

Column 1: Time [dddd:hh:mm:ss]
Column 2: Colour 1, BC temperature [°C]
Column 3: Colour 2, BC temperature [°C]
Column 4: Output node 1, temperature [°C]
Column 5: Output node 2, temperature [°C]
Column 6: Output node 3, temperature [°C]
Column 7: Output node 4, temperature [°C]
Column 8: Colour 1, sum of heat flows into object [W]
Column 9: Colour 1, sum of heat flows out of object [W]
Column 10: Colour 2, sum of heat flows into object [W]
Column 11: Colour 2, sum of heat flows out of object [W]

0000:00:00:00   -9.66   10.00   -0.79    2.11    7.99   -9.26    0.26   57.64   57.37    0.00
0000:01:00:00  -10.00   10.00   -0.79    2.11    7.99   -9.45    0.29   69.51   57.37    0.00
0000:02:00:00   -9.66   10.00   -0.80    2.11    7.99   -9.36    0.35   50.12   57.38    0.00
0000:03:00:00   -8.66   10.00   -0.81    2.11    7.99   -8.83   12.40   24.76   57.40    0.00
0000:04:00:00   -7.07   10.00   -0.80    2.11    7.99   -7.84   49.01   13.33   57.38    0.00
0000:05:00:00   -5.00   10.00   -0.76    2.14    7.99   -6.42   93.55    5.66   57.29    0.00
0000:06:00:00   -2.59   10.00   -0.66    2.21    8.00   -4.62  142.43    3.95   57.06    0.00
0000:07:00:00    0.00   20.00   -0.05    3.05    9.96   -2.55  184.90    2.48  184.52    0.00
0000:08:00:00    2.59   20.00    0.58    3.80   11.32   -0.33  216.85    1.49  168.39    0.00
0000:09:00:00    5.00   20.00    1.20    4.41   12.01    1.89  235.03    0.90  159.15    0.00
0000:10:00:00    7.07   20.00    1.90    5.04   12.54    3.98  237.44    0.59  151.36    0.00
0000:11:00:00    8.66   20.00    2.67    5.71   13.00    5.80  223.36    0.49  144.10    0.00
0000:12:00:00    9.66   20.00    3.49    6.40   13.43    7.23  193.31    0.44  137.10    0.00
0000:13:00:00   10.00   20.00    4.35    7.11   13.83    8.17  149.00    0.40  130.29    0.00
0000:14:00:00    9.66   20.00    5.19    7.80   14.21    8.57   93.33    0.47  123.68    0.00
0000:15:00:00    8.66   20.00    6.00    8.46   14.58    8.39   30.36    1.12  117.33    0.00
0000:16:00:00    7.07   20.00    6.74    9.07   14.92    7.66    0.24   38.34  111.30    0.00
0000:17:00:00    5.00   20.00    7.38    9.61   15.25    6.41    0.14  104.91  105.68    0.00
0000:18:00:00    2.59   20.00    7.89   10.06   15.54    4.75    0.29  166.66  100.53    0.00
0000:19:00:00    0.00   20.00    8.26   10.41   15.82    2.78    0.43  219.28   95.94    0.00
0000:20:00:00   -2.59   10.00    8.04    9.93   14.11    0.64    0.55  259.30    0.50   36.47
0000:21:00:00   -5.00   10.00    7.76    9.51   12.97   -1.53    0.64  283.90    1.10   25.01
0000:22:00:00   -7.07   10.00    7.45    9.19   12.49   -3.58    0.70  291.41    1.68   20.08
0000:23:00:00   -8.66   10.00    7.04    8.83   12.15   -5.36    0.73  281.38    2.43   16.51
```

0001:00:00:00	-9.66	10.00	6.54	8.42	11.86	-6.76	0.71	254.61	3.43	13.46
0001:01:00:00	-10.00	10.00	5.99	7.97	11.59	-7.68	0.65	213.03	4.66	10.71
0001:02:00:00	-9.66	10.00	5.41	7.51	11.33	-8.06	0.57	159.54	6.13	8.22
0001:03:00:00	-8.66	10.00	4.84	7.06	11.08	-7.87	0.52	97.88	7.80	6.00
0001:04:00:00	-7.07	10.00	4.32	6.64	10.84	-7.13	8.16	39.94	9.65	4.12
0001:05:00:00	-5.00	10.00	3.89	6.28	10.62	-5.88	55.12	21.77	11.57	2.54
0001:06:00:00	-2.59	10.00	3.56	6.00	10.41	-4.21	102.51	8.93	13.56	1.36
0001:07:00:00	-0.00	20.00	3.79	6.52	12.17	-2.23	149.64	4.84	142.87	0.00
0001:08:00:00	2.59	20.00	4.07	6.97	13.35	-0.08	186.62	3.26	129.74	0.00
0001:09:00:00	5.00	20.00	4.38	7.31	13.87	2.09	208.70	2.17	123.31	0.00
0001:10:00:00	7.07	20.00	4.80	7.70	14.24	4.14	214.19	1.44	118.15	0.00
0001:11:00:00	8.66	20.00	5.31	8.14	14.56	5.93	202.64	1.03	113.32	0.00
0001:12:00:00	9.66	20.00	5.91	8.64	14.86	7.34	174.80	0.85	108.59	0.00
0001:13:00:00	10.00	20.00	6.56	9.16	15.14	8.27	132.52	0.88	103.88	0.00
0001:14:00:00	9.66	20.00	7.22	9.69	15.41	8.65	78.74	1.15	99.23	0.00
0001:15:00:00	8.66	20.00	7.86	10.20	15.68	8.46	17.61	2.19	94.68	0.00
0001:16:00:00	7.07	20.00	8.45	10.67	15.93	7.72	0.06	50.73	90.33	0.00
0001:17:00:00	5.00	20.00	8.94	11.08	16.16	6.47	0.20	116.43	86.26	0.00
0001:18:00:00	2.59	20.00	9.33	11.41	16.38	4.80	0.35	177.19	82.55	0.00
0001:19:00:00	0.00	20.00	9.58	11.65	16.58	2.82	0.48	228.93	79.28	0.00
0001:20:00:00	-2.59	10.00	9.26	11.08	14.81	0.68	0.60	268.15	0.02	51.41
0001:21:00:00	-5.00	10.00	8.88	10.57	13.62	-1.49	0.69	292.03	0.10	38.28
0001:22:00:00	-7.07	10.00	8.48	10.17	13.08	-3.54	0.74	298.88	0.24	31.88
0001:23:00:00	-8.66	10.00	7.99	9.73	12.69	-5.33	0.76	288.26	0.57	26.91
0002:00:00:00	-9.66	10.00	7.42	9.24	12.35	-6.73	0.74	260.95	1.21	22.59
0002:01:00:00	-10.00	10.00	6.79	8.73	12.04	-7.66	0.69	218.87	2.12	18.68
0002:02:00:00	-9.66	10.00	6.15	8.21	11.74	-8.04	0.60	164.92	3.32	15.14
0002:03:00:00	-8.66	10.00	5.52	7.71	11.46	-7.85	0.53	102.84	4.70	11.92
0002:04:00:00	-7.07	10.00	4.95	7.25	11.19	-7.11	6.96	43.29	6.26	9.08
0002:05:00:00	-5.00	10.00	4.47	6.84	10.94	-5.86	53.42	24.28	7.92	6.63
0002:06:00:00	-2.59	10.00	4.10	6.51	10.70	-4.19	100.38	10.69	9.56	4.54
0002:07:00:00	-0.00	20.00	4.29	6.99	12.44	-2.21	146.50	5.29	136.22	0.00
0002:08:00:00	2.59	20.00	4.53	7.41	13.59	-0.07	183.67	3.63	123.58	0.00
0002:09:00:00	5.00	20.00	4.80	7.72	14.10	2.10	205.93	2.46	117.60	0.00
0002:10:00:00	7.07	20.00	5.19	8.07	14.45	4.16	211.59	1.68	112.85	0.00
0002:11:00:00	8.66	20.00	5.67	8.49	14.75	5.94	200.21	1.21	108.42	0.00
0002:12:00:00	9.66	20.00	6.25	8.96	15.03	7.35	172.53	1.01	104.04	0.00
0002:13:00:00	10.00	20.00	6.87	9.46	15.30	8.28	130.44	1.03	99.67	0.00
0002:14:00:00	9.66	20.00	7.51	9.96	15.56	8.66	76.84	1.32	95.32	0.00
0002:15:00:00	8.66	20.00	8.13	10.45	15.81	8.47	15.92	2.42	91.06	0.00
0002:16:00:00	7.07	20.00	8.69	10.90	16.05	7.73	0.06	52.51	86.97	0.00
0002:17:00:00	5.00	20.00	9.17	11.30	16.28	6.48	0.21	118.08	83.14	0.00
0002:18:00:00	2.59	20.00	9.54	11.61	16.49	4.81	0.35	178.72	79.66	0.00
0002:19:00:00	0.00	20.00	9.77	11.84	16.68	2.83	0.49	230.35	76.60	0.00
0002:20:00:00	-2.59	10.00	9.43	11.25	14.90	0.68	0.60	269.46	0.01	53.88
0002:21:00:00	-5.00	10.00	9.04	10.73	13.70	-1.49	0.69	293.24	0.06	40.55
0002:22:00:00	-7.07	10.00	8.63	10.32	13.15	-3.54	0.75	300.01	0.17	33.94
0002:23:00:00	-8.66	10.00	8.13	9.87	12.76	-5.33	0.77	289.30	0.43	28.74
0003:00:00:00	-9.66	10.00	7.55	9.37	12.41	-6.73	0.75	261.91	0.99	24.20

E.5. Drawing graphs

From a report in the Text Output window a graph of time functions of report items can be drawn, e.g. in Microsoft Excel. Here is a procedure that can be used:

- For the time axis it is best to have time values in seconds (type [s] in the Report Definition window) instead of values in days, hours, minutes and seconds (type [dddd:hh:mm:ss]). This is because the seconds can easily be rescaled in Microsoft Excel to a more suitable unit (e.g. hours, as in the figure below).
- Select the wanted area in the Text Output window (with the report output), and copy it into the clipboard (using *Edit > Copy*). For the figure below we selected the time column (but recalculated with unit in seconds) and the columns with temperature data (select columns in Microsoft Word using <Alt+Shift>).
- Paste the contents of the clipboard in Microsoft Excel.
- Insert a new row on top of the data (*Insert > Rows*) and add names as column headers for the different output items. These names will be printed in the chart legend.
- Select all data and use the Chart wizard (menu command *Insert > Chart…*) with chart type: XY (Scatter) to make a graph.

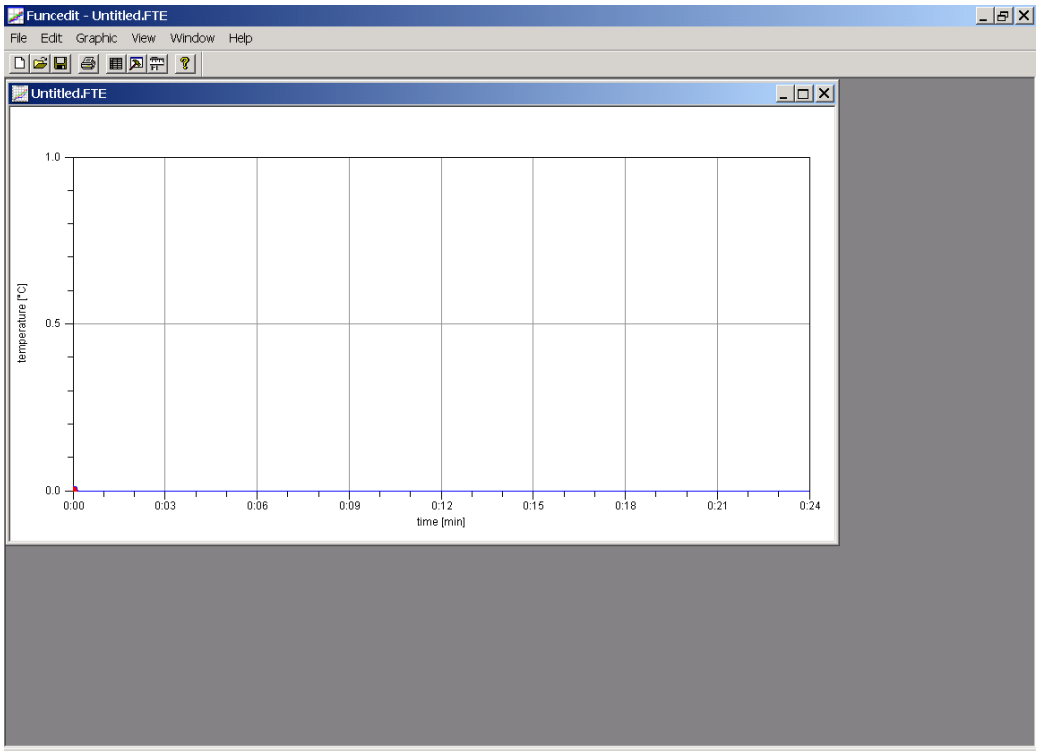

25
20
15
10
5
0
-5
-10
-15
0
6
12
18
24
30
36
42
48
54
60
66
72
Temperature [°C]
Time [h]
Outside
Inside
3D corner
2D corner
Wall inside
Wall outside

CHAPTER F PROGRAM FUNCEDIT

F.1. Introduction

The program FUNCEDIT is a utility program to edit and visualise function files for use in the non-steady state Physibel programs (VOLTRA, SECTRA, BISTRA, CAPSOL), where these functions are used as dynamic boundary condition specifications.

After starting FUNCEDIT, or creating a new function using the command *File > New*, a null temperature function of length 24 hours (with hourly values of 0°C) is displayed.



An existing function file on disk is read using the command *File > Open…*. The function type can be chosen in the Open dialog box.

F.2. Function type

The following function types are available:

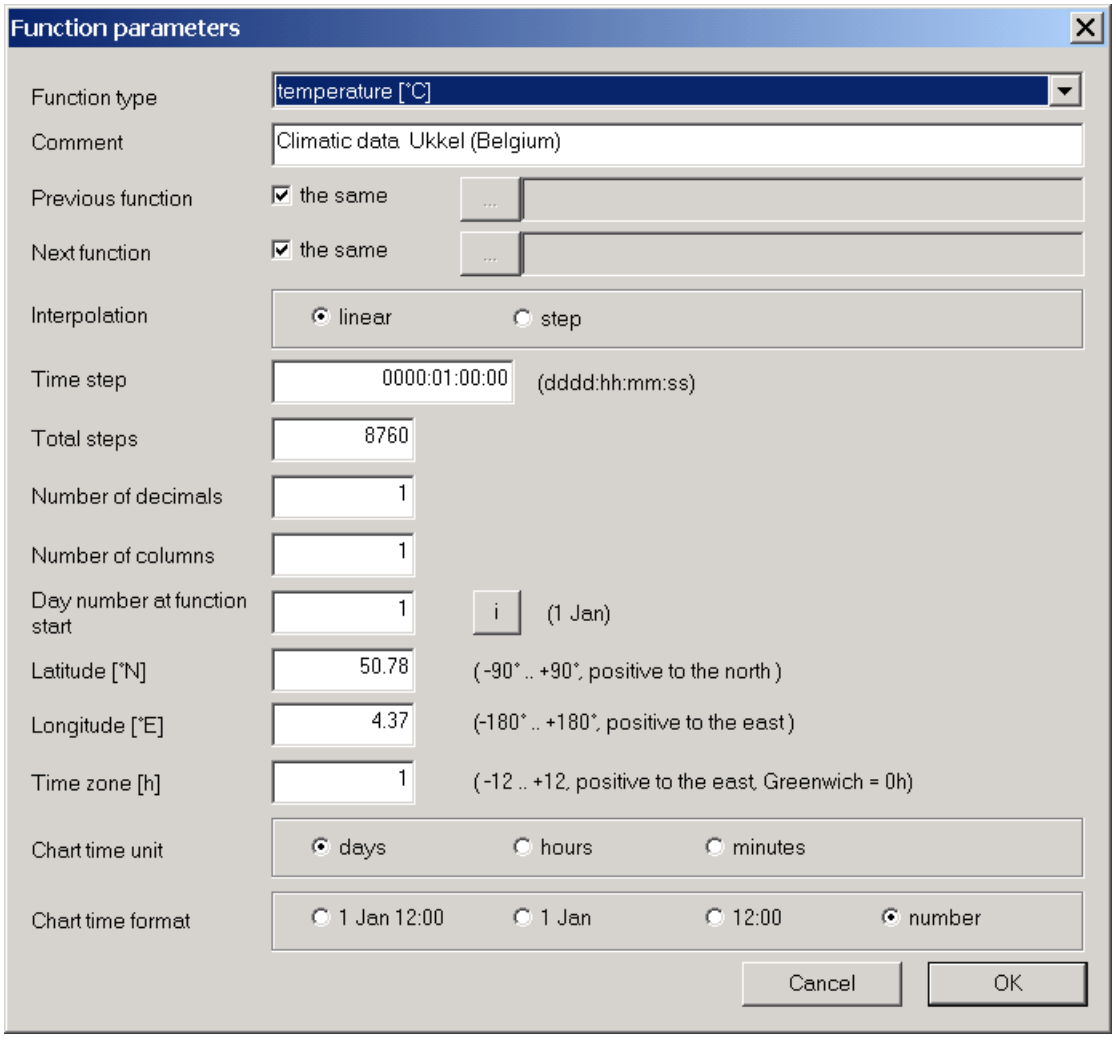
	unit	extension	use in VOLTRA & SECTRA
temperature	[°C]	.fte	boundary condition temperature
horizontal global solar radiation	[W/m^2]	.fsg	boundary condition solar zone
horizontal diffuse solar radiation	[W/m^2]	.fsd	boundary condition solar zone
direct solar radiation	[W/m^2]	.fsb	not used
solar radiation	[W/m^2]	.fse	not used
infrared radiation	[W/m^2]	.fir	boundary condition heat flux
power	[W]	.ffh	boundary condition power
thermal conductivity	[W/(m.K)]	.fco	material property time-dependent thermal conductivity
surface heat transfer coefficient	[W/(m².K)]	.fht	boundary condition total surface heat transfer coefficient or

			convective heat transfer coefficient
ventilation rate	[/h]	.fvr	ventilation volume flow rate [m^3/s]

Remark
The ventilation rate in FUNCEDIT is shown with unit /h, which is used in the Physibel program CAPSOL. However in VOLTRA the same function type is used for ventilation volume flow rates, with unit m^3/s. So for VOLTRA ventilation functions the unit specifier [/h] in FUNCEDIT should be read as [m^3/s].

F.3. Function parameters

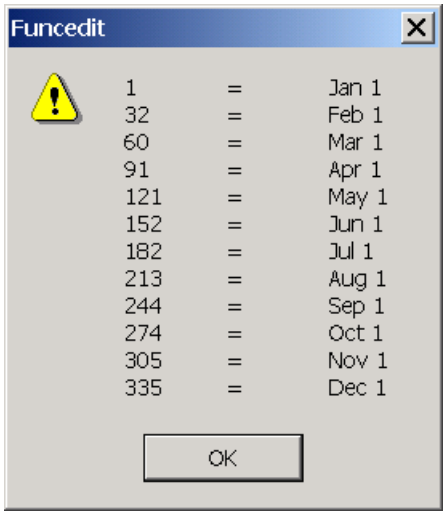
General header information of a function file is edited via the command *Edit > Parameters*.



A dialog box is opened where the following parameters can be edited:
- Function type: see section F.2.
- Comment: text description of the function.
- Previous function and next function: file name of a function that precedes the current function (previous function) or comes next to the current function (next function). The previous and/or next function may be the same as the current function, in which case the check box “the same” is marked.
  If the time space of a VOLTRA data file is larger than the time space of the function definition, it is necessary to know which function comes next to the current one. In case a start-up calculation is used, a previous function is required. If the previous and the next function are

checked as the same, then the current function corresponds to the definition of an infinite periodic function, with period the length of the current function.

- Interpolation: linear or step. Intermediate function values are either obtained by linear interpolation (linear function) or remain constant during the whole time step interval (step function).
- Time step [dddd:hh:mm:ss]: time interval between two successive function values in the function data window (see section F.4).
- Total steps: number of time steps required to span the total function length. This number is equal to the number of function values minus 1. The function length or duration equals the time step multiplied by the total number of steps.
- Number of decimals: number of digits after the decimal point, for all function values in the function data window (see section F.4) and in the function file.
- Number of columns: used in the function data window (see section F.4) and in the function file.
- Day number at function start [1..365]: day number in the year on which the function starts. The "i" button gives information about the start days of each month.



- Latitude [°N], longitude [°E] and time zone [h]: to position a function climate station on the globe.
- Chart time unit and chart time format: labelling information for the time axis in the function chart. This information is not stored in the function file.

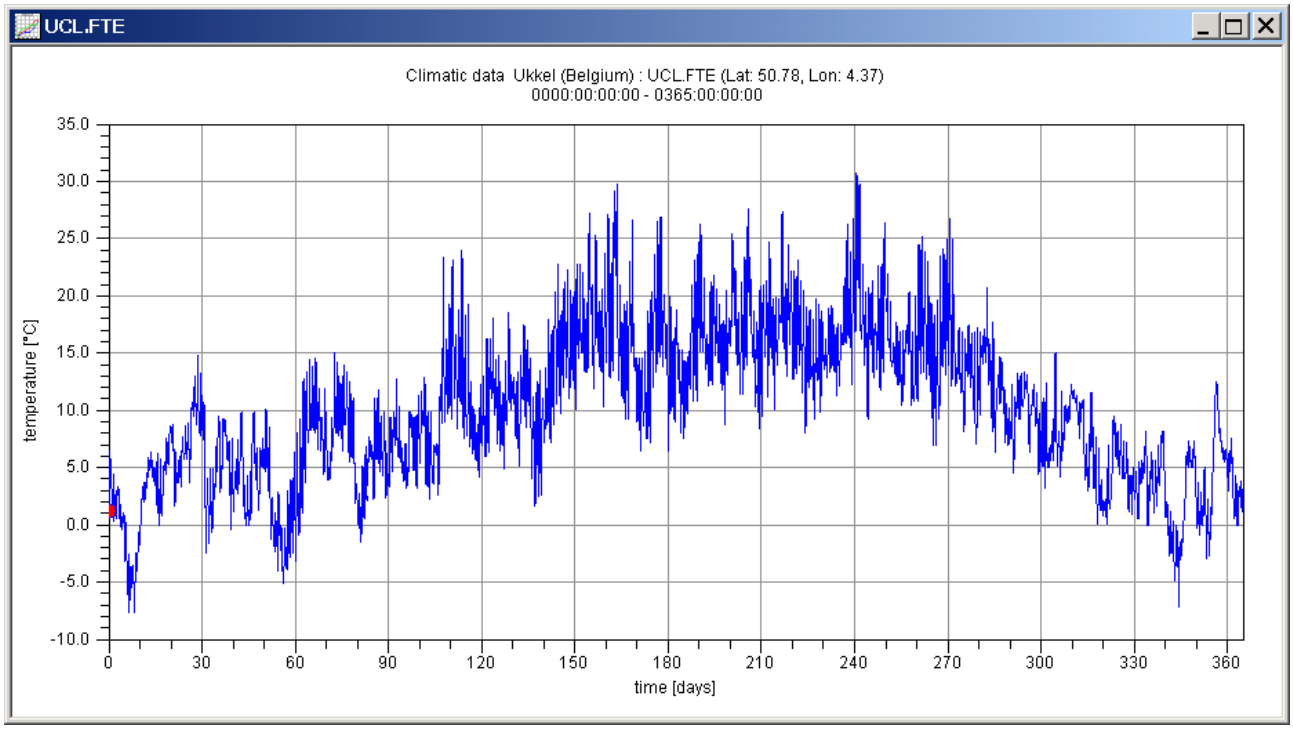
F.4. Function data

The function values at regular time step intervals can be edited in the function data window, opened with the command *Edit* > *Data*. The table format is controlled by the function parameters (see section F.3).

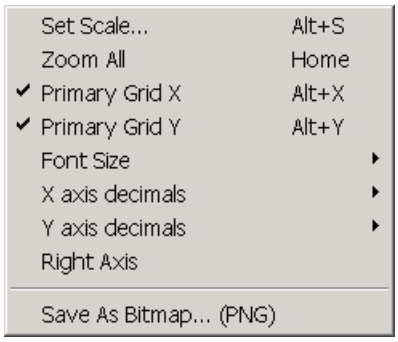
In the left (grey) column a time indication of the first value in the row is given. The table can be navigated by the mouse or by the arrow keys.
A new value can be inserted after the current one using the command *Edit* > *Insert After* or the <Insert>-key. The "total steps" parameter in the function parameters dialog box is adapted accordingly.
A value can be deleted using the command *Edit* > *Delete Value* or the <Delete>-key.
Individual table cells can be copied and pasted by using the commands *Edit* > *Copy* (or <Ctrl+C>) and *Edit* > *Paste* (or <Ctrl+V>).

F.5. Graphic parameters

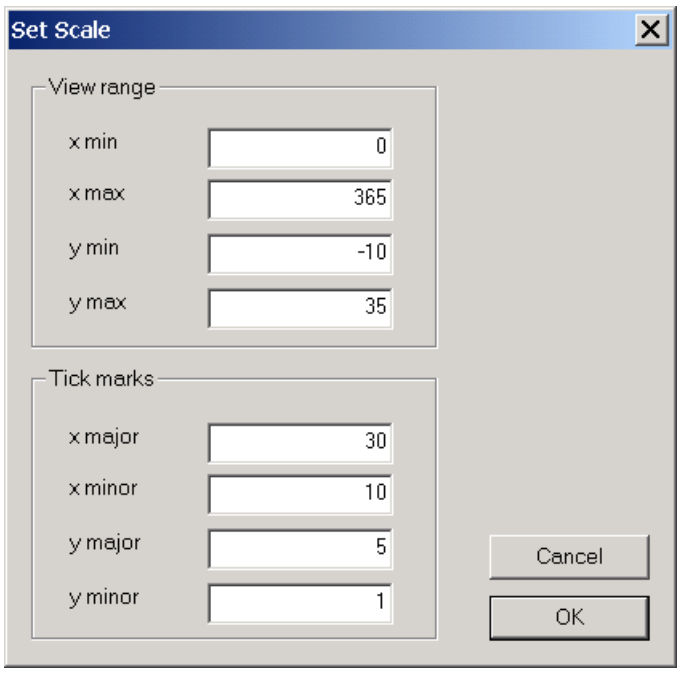
The window that is opened when a new function is created or an existing function file is read, contains a graphic representation of the numerical function data entered in the data window.
The red point in the graph corresponds to the function value in the current cell of the data window.



The parameters about the graph can be edited in the Graphic submenu.



The command *Graphic* > *Set Scale…* opens a dialog box containing scale parameters.
The view range for both axes and tick mark distances can be set.



When a rectangle is drawn in the graph, with mouse dragging holding down the left mouse button, a zoom rectangle is defined. The corresponding zoom view is drawn when the left mouse button is released. The initial total view (with view range as defined in the Set Scale dialog box) can be restored by using the command *Graphic > Zoom All* or pressing the <Home>-key.

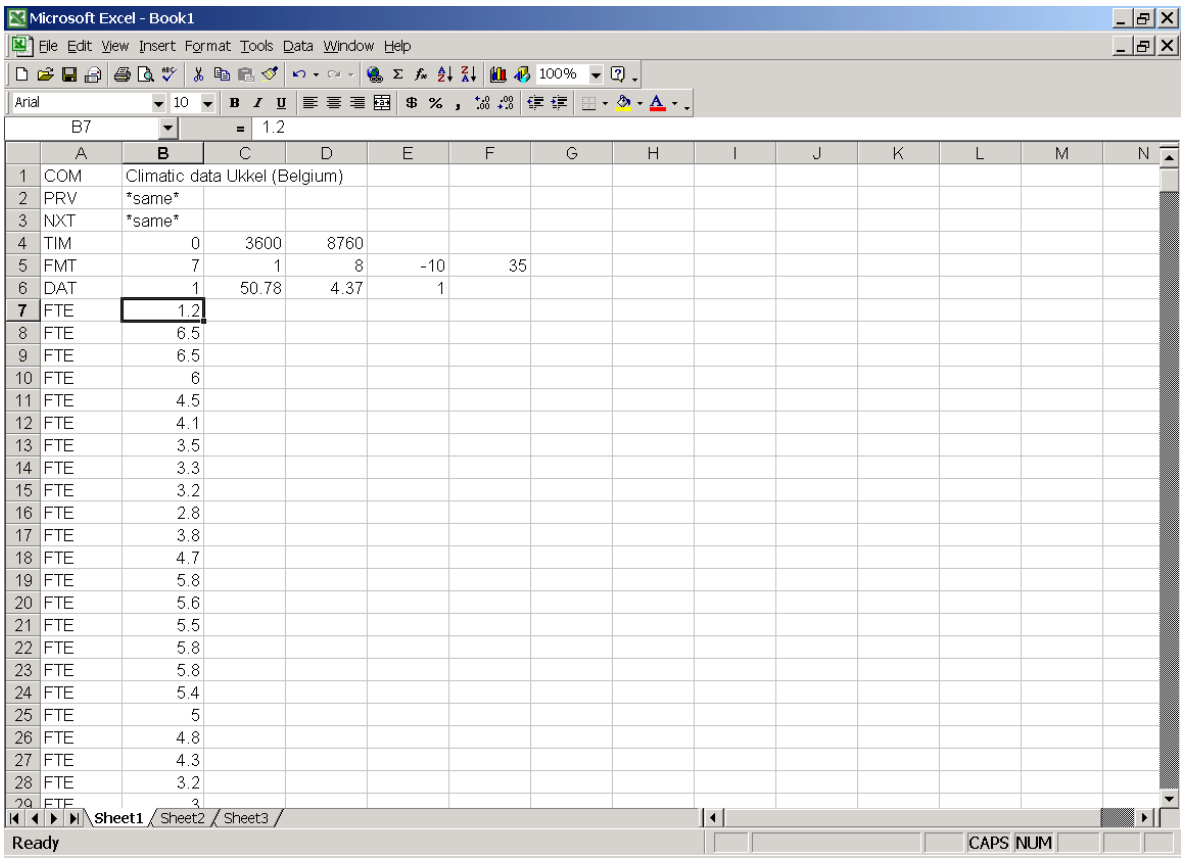
The commands *Graphic > Primary Grid X* and *Graphic > Primary Grid Y* enable to show grid lines through the primary tick marks on both axes X and Y.

The command *Graphic > Right Axis* allows to draw also a vertical axis with tick marks at the right side of the chart border.

The command *Graphic > Save As Bitmap (PNG)* opens a dialog box where you can enter the file name and size of the .png file, which will be saved in the same directory as where the function is stored.

F.6. Using a spreadsheet program to create functions

A function file can also be created using Microsoft Excel or another spreadsheet program.
The spreadsheet contains 6 header rows (starting with the keywords COM, PRV, NXT, TIM, FMT and DAT) followed by data rows with function values. The syntax of the input data is given in the table below. Save the file (as text) in the function files directory, with the extension corresponding to the function type (cf. section F.2).
If an existing function file, created with FUNCEDIT, has to be modified using a spreadsheet program, it is recommended first to set the parameter “number of columns” in the Function Parameters dialog box equal to 1. Then there will be only 1 column with function values in the spreadsheet (as in the figure below).



A	B	C	D	E	F
1 COM	Climatic data Ukkel (Belgium)				
2 PRV	*same*				
3 NXT	*same*				
4 TIM	0	3600	8760		
5 FMT	7	1	8	-10	35
6 DAT	1	50.78	4.37	1	
7 FTE	1.2				
8 FTE	6.5				
9 FTE	6.5				
10 FTE	6				
11 FTE	4.5				
12 FTE	4.1				
13 FTE	3.5				
14 FTE	3.3				
15 FTE	3.2				
16 FTE	2.8				
17 FTE	3.8				
18 FTE	4.7				
19 FTE	5.8				
20 FTE	5.6				
21 FTE	5.5				
22 FTE	5.8				
23 FTE	5.8				
24 FTE	5.4				
25 FTE	5				
26 FTE	4.8				
27 FTE	4.3				
28 FTE	3.2				
29 FTE	3				

row number	code	input data				
	column A	column B	column C	column D	column E	column F
1	COM	comment				
2	PRV	name of the previous function *				
3	NXT	name of the next function *				
4	TIM	interpolation: 0 = linear / 1 = step	time step (in seconds)	total number of steps		
5	FMT	total number of characters of the function values	number of digits after decimal point	number of columns of function values	minimum ordinate	maximum ordinate
6	DAT	date number at function start	latitude	longitude	time zone	
7 - ... - (7 + total steps)	function type**	function value	(function value)	(function value)	(function value)	(function value)

* The extension of the file name may be omitted; use the name *same* to specify the same previous / next function.

** The function type as described in section F.2.

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