

CAPSOL

computer program to calculate
multizonal transient heat transfer

version 5.0w

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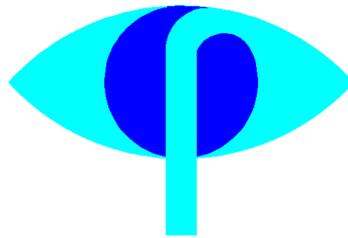


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CHAPTER A INTRODUCTION

A.1. Short description of CAPSOL

CAPSOL is a thermal building simulation program to calculate multizonal dynamic heat transfer, which takes into account heat capacity (CAP-) and solar radiation (-SOL).

The required input is:

- Geometric model of the building zones and environment (external obstacles for solar radiation).
- Thermal and solar properties of walls, wall layers and zones.
- Climate data (e.g. hourly values of temperatures, global and diffuse solar radiation on a horizontal surface) and geographic location.
- Heat gains from internal heat sources.
- Comfort requirements (set-point temperatures and ventilation rates).
- Parameters of heating, cooling, ventilation and sunshade control systems.
- Calculation period and time step.

Every time step an energy balance is calculated based on the changing boundary conditions and controls. A solar processor for the direct and diffuse solar radiation is used on the 3D model to get accurate solar loads on walls, glazings and internal zones. Conduction and heat storage in walls are calculated one-dimensional. Infrared radiation and diffuse solar radiation are distributed using view factors, automatically calculated from the 3D model.

The calculation can be executed interactively step by step, showing results filled on the 3D geometry or with charts.

The possible output is:

- Energy needs for space heating and cooling.
- Contribution of passive solar gains.
- Use of building inertia for heat accumulation (e.g. with intermittent heating or cooling).
- Temperature transgressions and overheating.
- Response time of heating and cooling on thermal comfort.
- Detailed analysis of transmission and ventilation heat transfer.

CAPSOL can be used for optimising the energy performance and thermal comfort, and assessing the effects of possible energy conservation measures.

A.2. Normative references

- EN 410, Glass in building – Determination of luminous and solar characteristics of glazing.
- EN 673, Glass in building – Determination of thermal transmittance (U value) – Calculation method.
- ISO 13370, Thermal performance of buildings – Heat transfer via the ground – Calculation methods.
- ISO 13786, Thermal performance of building components – Dynamic thermal characteristics – Calculation methods.
- ISO 13790, Energy performance of buildings – Calculation of energy use for space heating and cooling.
- ISO 13791, Thermal performance of buildings – Calculation of internal temperatures of a room in summer without mechanical cooling – General criteria and validation procedures.
- ISO 13792, Thermal performance of buildings – Calculation of internal temperatures of a room in summer without mechanical cooling – Simplified methods.
- EN 15255, Energy performance of buildings – Sensible room cooling load calculation – General criteria and validation procedures.

- EN 15265, Thermal performance of buildings – Calculation of energy needs for space heating and cooling using dynamic methods – General criteria and validation procedures.

A.3. System requirements

- CAPSOL is a 32-bit Windows program.
- CAPSOL uses OpenGL for hardware accelerated graphics. OpenGL uses two system files glu32.dll and opengl32.dll in the Windows system folder.
- The installed RAM (preferably 1Gb up to the maximum of 2 Gb) determines the available calculation power. Memory intensive operations may be the view factor calculation, the system solution for a large number of system nodes, the storage of intermediate solutions for a combination of a small calculation time step with a long calculation period. The memory usage can be followed with the Windows Task Manager (Performance tab).
- A software licence of CAPSOL is protected with a dongle.

A.4. Hardware key protection

The software CAPSOL is protected by a hardware key, to prevent illegal use of the software. In this way both the client and software developer are better protected for their investment and development effort. It is strongly recommended to take a financial assurance for loss of the key by theft or any other incidence.

Before using CAPSOL, the hardware key must be connected and the key driver installed. Run from the distribution CD: [CD-drive]:\Sentinel\Driver\Sentinel Protection Installer 7.6.6.exe (or a more recent version, which can be downloaded from <http://www.safenet-inc.com>). After installation see C:\Program Files\SafeNet Sentinel\Sentinel Protection Installer\7.6.6\English\ReadMe.pdf.

A.5. Overview of delivered files and file structure

CAPSOL is installed (when the user accepts the default destination) in the directory C:\Program Files\Physibel.

The following directory structure is used:

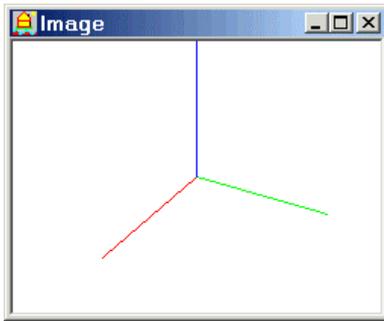
...\Physibel\Capsol5	CAPSOL program	Capsol.exe, imagelib.dll, RainbowColor.rgb
	wall type editor	WallTypeEdit.exe, Patterns.pat
	function editor	Funcedit.exe
...\Physibel\Capsol5\Data\Project	all data files related to a project	
	CAPSOL data files	*.cps files
	wall type data files	*.cwt files
	function data files (+ climate data)	*.fte, *.fsg, *.fsd files
	calculated view factors	*.vwf files
	time step solution files	*.sol files
	graphic output	*.png files
	text output	*.txt files
...\Physibel\Materials	material databases	*.phm files
	material editor	MatEdit.exe, MatEdit.prm, imagelib.dll, Patterns.pat
...\Physibel\Climates	climate files	*.fte, *.fsg, *.fsd files
...\Physibel\Manuals	manuals	*.pdf files

CHAPTER B DRAWING THE GEOMETRY

B.1. Drawing lines

Two input windows are used to draw lines:

- The Image window (*Edit > Image* or program function key F11).
- The Drawing Vector window (*Edit > Drawing Vector* or F12).

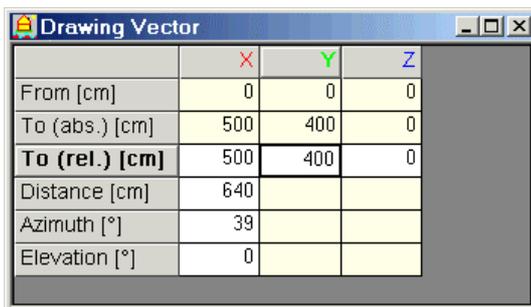


The Image window shows the coordinate axes of the coordinate system XYZ as a red (for X), a green (for Y) and a blue (for Z) line. The figure at the left shows the Image window for a new project (*File > New*).

The Drawing Vector window allows the enter new points, which are positioned with reference to the last entered point (i.e. relative coordinates). The Image window shows a dotted line between the last entered point (where the red, green and blue axes are positioned) and the new point. All coordinates are (positive or negative) integer values, expressed in cm. The spherical coordinates (distance, azimuth and elevation) can also be used to enter a new point (distance in cm, azimuth and elevation angles in $^{\circ}$).

The figure below shows the Drawing Vector window with the following fields:

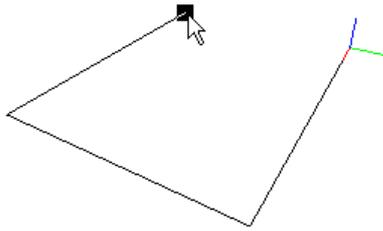
- From [cm]: Absolute coordinates in cm of starting point of current drawing vector (in this starting point the red, green and blue coordinate axes are positioned).
- To (abs.) [cm]: Absolute coordinates in cm of end point of current drawing vector.
- To (rel.) [cm]: Relative coordinates in cm (with reference to the starting point) of end point of current drawing vector.
- Distance [cm]: Distance in cm of current drawing vector.
- Azimuth [$^{\circ}$]: Horizontal angle from positive X axis to horizontal projection of drawing vector.
- Elevation [$^{\circ}$]: Vertical angle from horizontal projection of drawing vector to drawing vector.



The following commands are available to define lines:

- *Geometry > Line Start* or shortcut key F4: defines the starting point of a line. The reference point (crosspoint of the red, green and blue axes) moves to this starting point.
- *Geometry > Draw To* or shortcut key F5: defines the end point of a line. A line is drawn from the last entered point (“From”) to the end point (“To”), and this new point becomes the new reference point (crosspoint of the red, green and blue axes).

In this way the consecutive line segments of a polyline can quickly be drawn by defining the consecutive vertices (each time with reference to the previous vertex) and pressing F5.



In select mode (*Image > Select* or shortcut key F1) a previously defined point can be selected in the Image window by moving the mouse cursor over that point.

A selected point is highlighted in the Image window showing a little (colour inverted) square over that point.

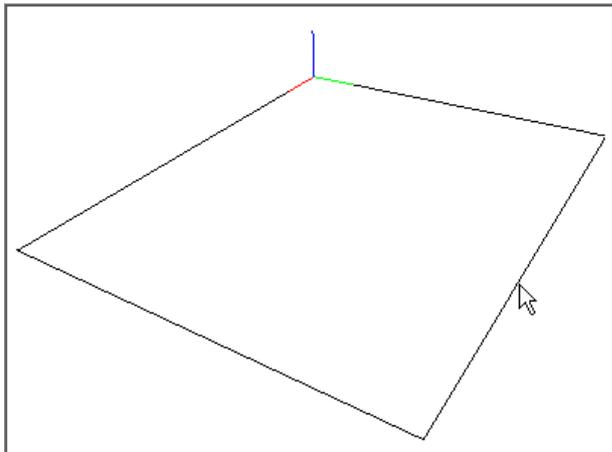
By pressing the left mouse button on a selected point, the coordinates of this point are copied as new point in the Drawing Vector window.

B.2. Drawing a simple wall

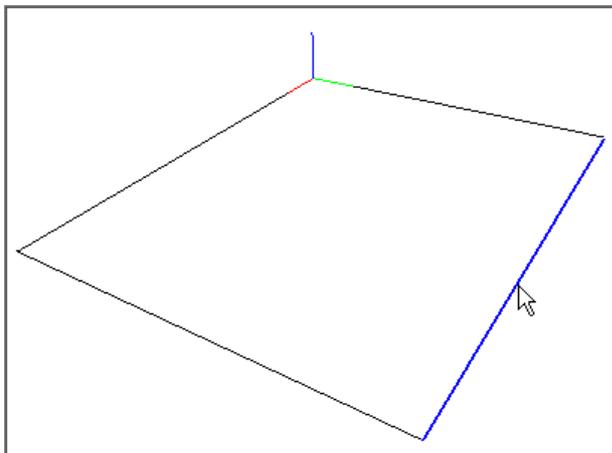
When the lines of the perimeter of a wall are drawn (as a closed polyline), the wall surface can be defined in the following way.

Select a line of the perimeter (in “select mode” using F1) by clicking the left mouse button on that line, so that it becomes a thick blue line.

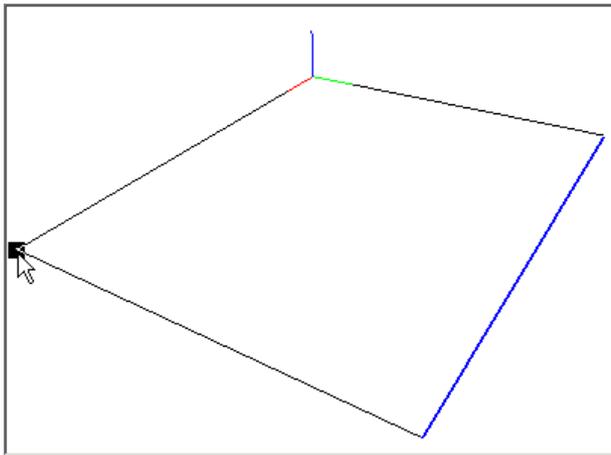
Then using the mouse select the end point of a line connected to an end point of the selected line, and click the left mouse button on that selected point.



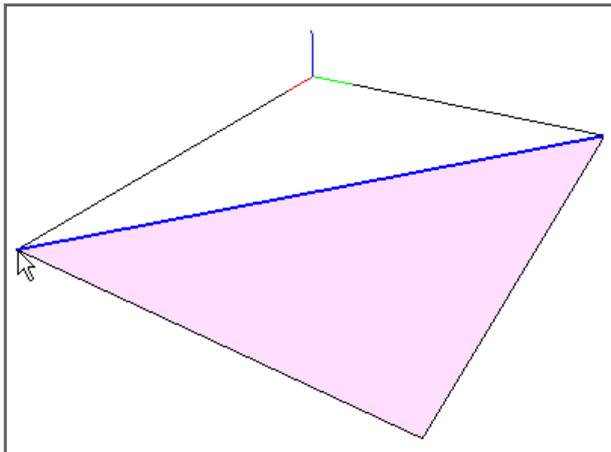
Step 1:
Move the mouse cursor to a line of the closed perimeter.



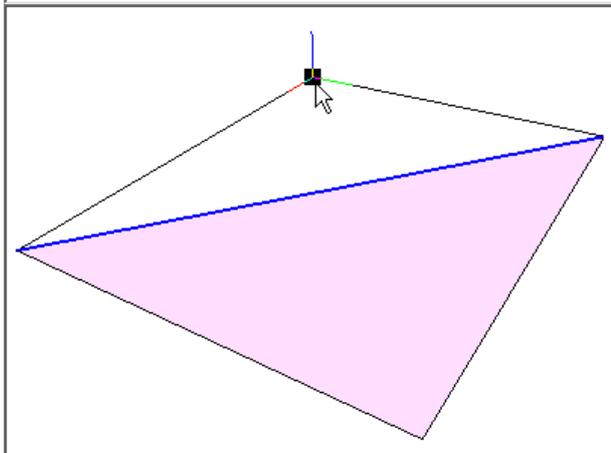
Step 2:
Click the left mouse button to select the line.
The selected line becomes blue.



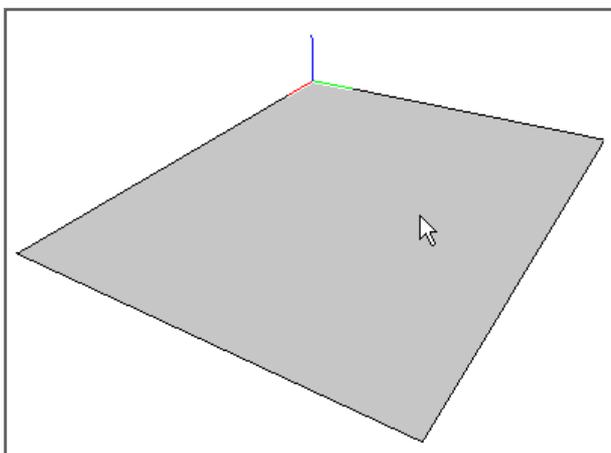
Step 3:
Select a point that is the end point of a line connected to the selected (blue) line.



Step 4:
The triangle formed by both end points of the selected line together with the selected point is coloured in pink, and the new line created by this triangle (different of the original selected line and the other existing line) becomes the new selected line.

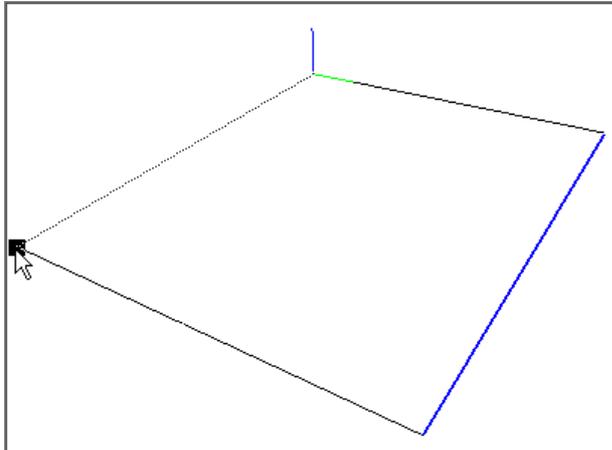


Step 5:
Repeat step 3 and 4, starting from the current selected (blue) line, which is a diagonal of the quadrangular face we are creating.



Step 6:
After clicking the final vertex of the polygonal face, a new wall is created (cf. Walls window, as in the figure below), and the wall face is coloured in light grey in the Image window.

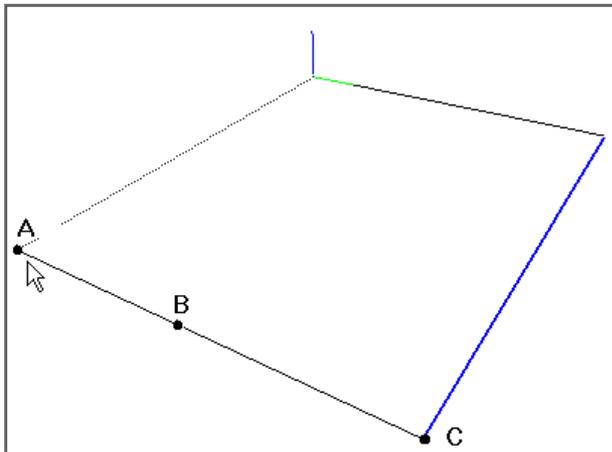
No.	Show	Wall Type	From Zone	To Zone	hg1 [W/m ² K]	hc1 [W/m ² K]	hg2 [W/m ² K]	hc2 [W/m ² K]	Area [m ²]	Weight [kg]
1	YES								20.00	0



Remark to step 4:

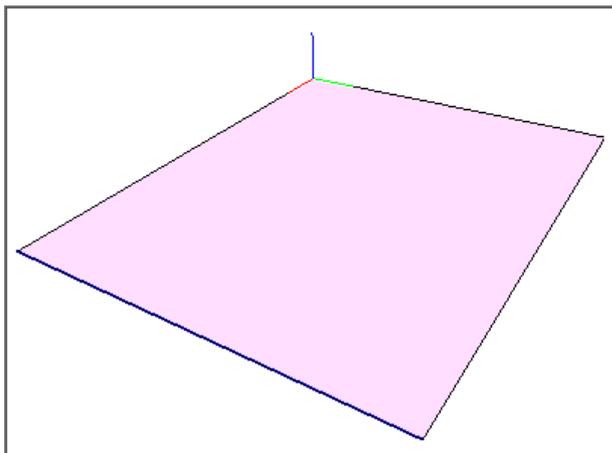
It may happen that no triangle is formed after selecting a point opposite to the selected (blue) line.

This is because the selected point is not directly connected to an end point of the selected (blue) line, although there may be a visible connection in the Image window. In fact this visible connection line may consist of several smaller line segments (cf. next figure).



Two lines (AB and BC) are defined in the geometric model, but not the wanted line AC. The solution to this problem (in creating the pink triangle of step 4) is to define explicitly the line AC:

Move the mouse cursor to point A and define it as starting point of a new line (press F4). Then move the mouse cursor to point C and define it as end point of a new line (press F5). Now return to step 4 to fill the triangle.

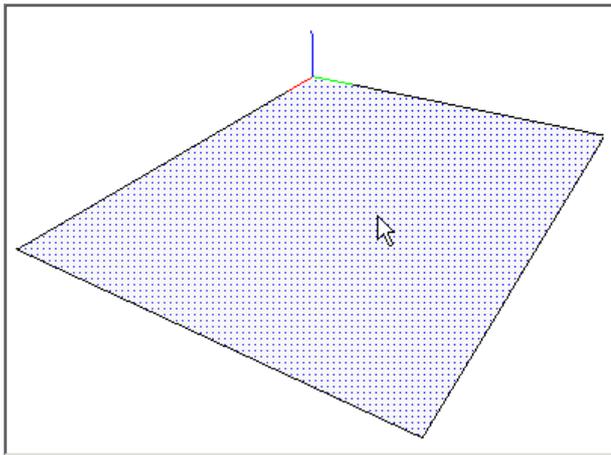


Remark to step 6:

It may happen that the face remains coloured in pink and the blue selection line does not disappear, though the entire face is filled.

This is because one (or more) of the visible edges are not present as well defined lines, but is (or are) composed of smaller line segments (as AB and BC in the previous figure).

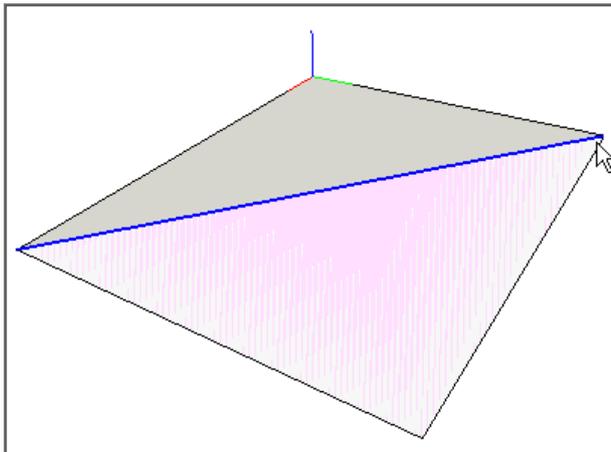
After deleting the pink face (cf. next figure), redefine explicitly all wanted contour lines (selecting the successive vertices with the mouse and pressing F5), and repaint the face.



Select face:

A face can be selected by moving the mouse cursor inside the face and clicking the left mouse button (in “select” mode, which is active after pressing F1).

A blue dotted pattern shows the selected face. The selected face can be deleted using the command *Geometry > Delete* or pressing the <Delete> key.



Remark to select face:

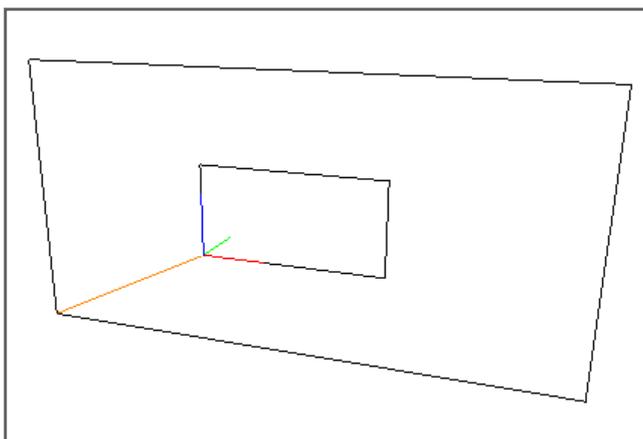
A wall face may (unintentionally) overlap another face.

A moiré pattern as in the left figure shows the overlapping parts.

Such overlapping faces must be deleted to have a clean unambiguous geometric model (see also section B.8).

B.3. Drawing a wall with window

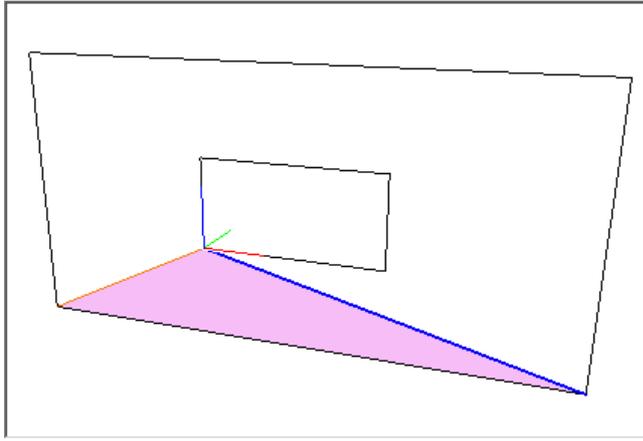
To draw a polygonal face with a hole inside, we need to draw a diagonal to be able to fill the face.



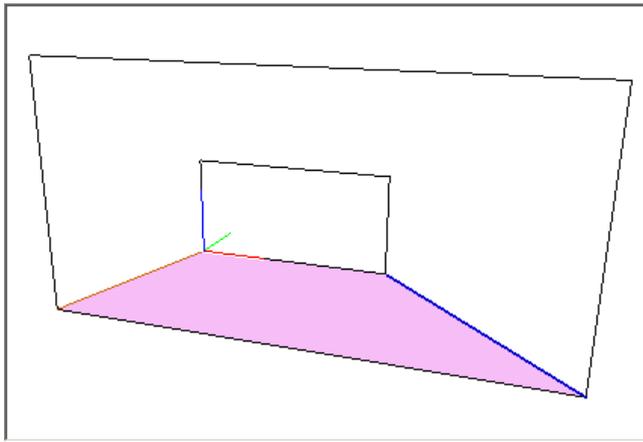
Move to one end point of the diagonal using the command *Geometry > Line Start* or using the shortcut key F4.

Then select the second end point using the left mouse button, and choose the command *Geometry > Diagonal* or F6.

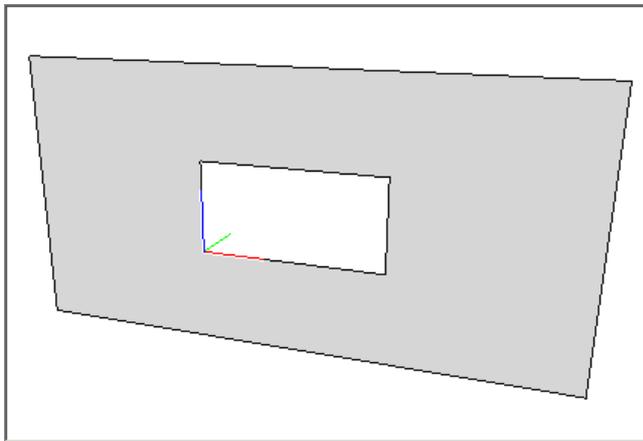
The diagonal is drawn in orange.



Now the diagonal can be used in drawing the triangulation of the face between the outside and inside polygon, using the method of the previous paragraph.

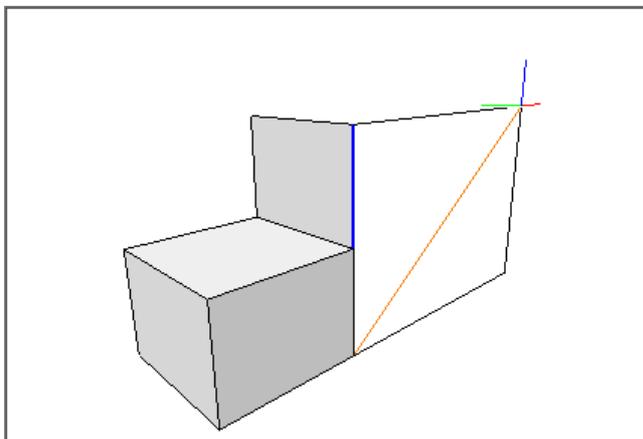


Then select a connected vertex on one of both polygons to proceed the triangulation (as in step 4 of section B.2).

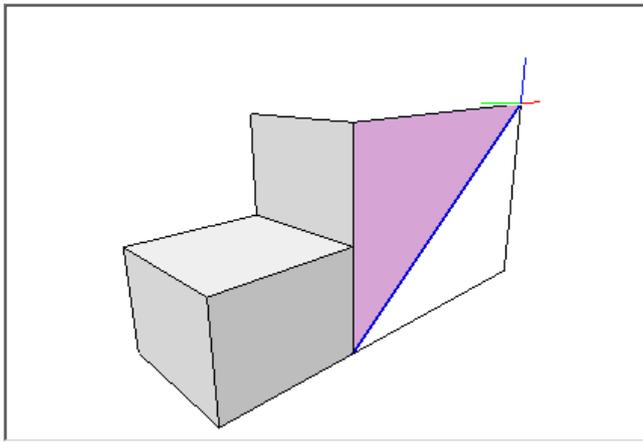


Continue the triangulation until the face between both polygons is completely filled, and a new wall (with reference to this face) is added to the Walls window.

Notice the original diagonal is removed from the representation, and the completed triangulation is filled in grey.



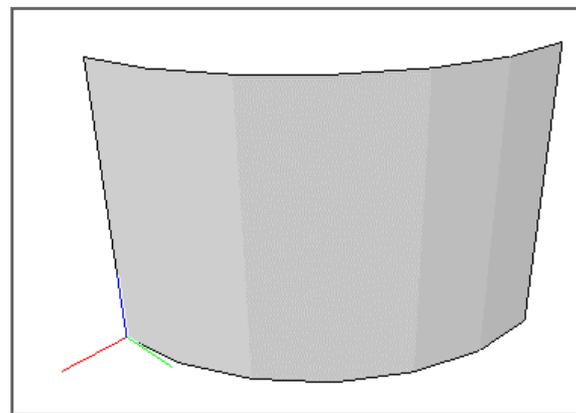
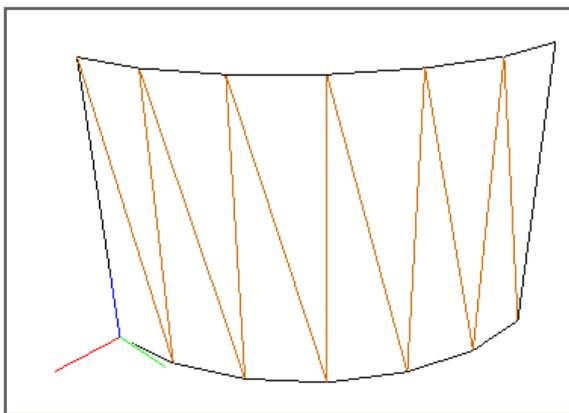
Sometimes it is also useful to add diagonals in filling simple walls (as in the left figure), when the wanted wall edges cannot be selected, because of other overlapping lines (as e.g. for the left edge of the new wall).



Now select the diagonal as base line for filling the triangulation of the new face.

B.4. Drawing a curved wall

Using an appropriate triangulation it is possible to draw any curved wall, as in the figure below.



Important remarks

- In the system of equations, used in the thermal calculation, each wall surface is represented by only one node. However the total wall area, weight, and the thermal load (e.g. from solar radiation) are calculated based on all triangles (with possibly different orientations) of the face triangulation. The total thermal load is then imposed to the single surface node. In the Image window all output refers to the (averaged) values (of solar irradiation, absorbed solar radiation, temperature, fluxes or cumulated energy) in the surface node.
- The area of each triangle of a wall triangulation should be larger than 100 cm^2 , otherwise this triangle is neglected in the view factor calculation (cf. section B.13).

B.5. Painting the wall types

The thermal characteristics of the different layers of a wall are defined in a wall type file (with file extension .cwt). Wall type files are created with the Wall Type Editor (cf. Chapter F).

The wall type files (*.cwt) used in a CAPSOL project must be loaded in the Wall Types window (cf. section C.1) via wall type records which refer to the wall type file names (via the field “Name”).

The figure below shows an example with 1 wall type referring to the wall type file *External Wall.cwt*.

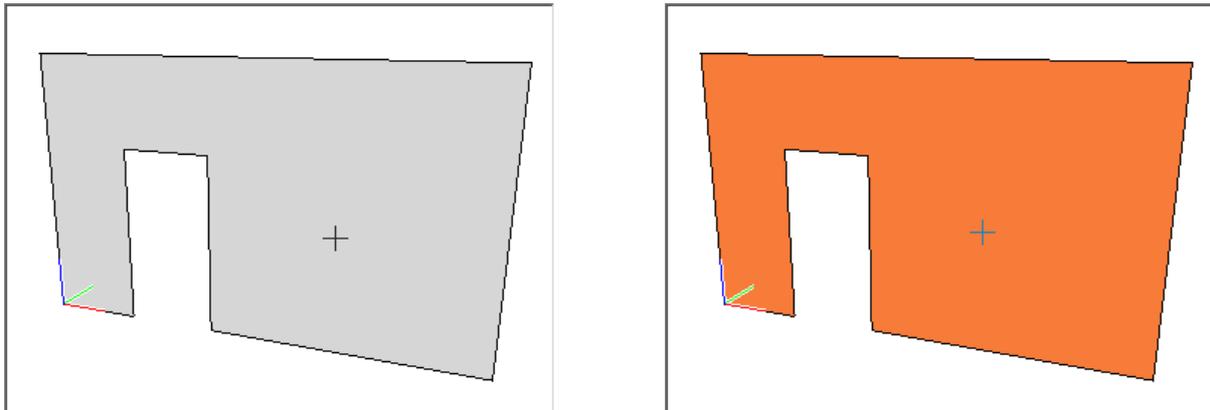
No.	Name	Show	Thickness [cm]	Weight [kg/m ²]
1	External Wall	YES	34.5	351.3

The current wall type (determined by the active cell, surrounded by bold lines) can be attributed to a wall using the paint tool. Select *Image > Paint* or the shortcut key F2 (which alters the mouse cursor in the Image window from an arrow into a crosshair).

Select *View > Wall Type* to activate the option of colouring walls in the Image window using the colours of their attributed wall types.

Click the left mouse button within the wall. The wall is now painted using the colour of the current wall type (see second column in the Wall Types window).

The figures below show the wall before (left figure) and after (right figure) the mouse click.



The Walls window is adapted accordingly (column “Wall Type”).

No.	Show	Wall Type	From Zone	To Zone	hg1 [W/m ² K]	hc1 [W/m ² K]	hg2 [W/m ² K]	hc2 [W/m ² K]	Area [m ²]	Weight [kg]
1	YES	External Wall							13.00	4568

The painting can be made undone, by selecting *Image > Unpaint* or Ctrl+F2, and clicking inside the wall using the left mouse button.

B.6. Painting the zones

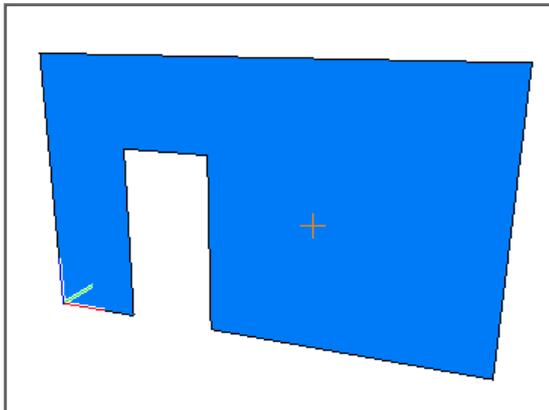
Each wall must be painted again to identify the zones at both sides of it.

Suppose the zones used in the CAPSOL project are defined in the Zones window (cf. section C.2) as in the figure below. The first zone (zone no. 1) must always be the “solar zone”, i.e. the exterior with the sun.

No.	Name	Show	Volume [m ³]	ρ [kg/m ³]	Weight [kg]	c [J/kgK]	Rad.
1	Exterior	YES		1.2		1000.0	
2	Interior	YES		1.2		1000.0	

Select *View > Zone* (to view the zones in the Image window) and choose *Image > Paint* or F2.

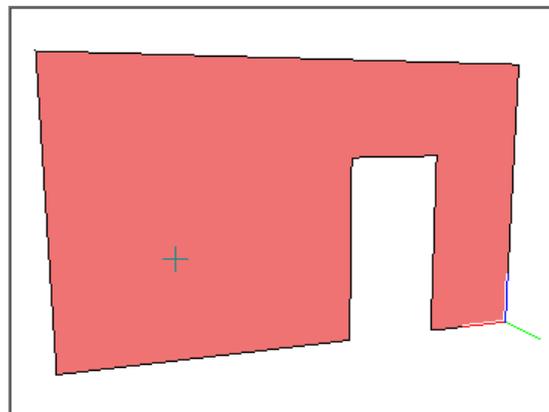
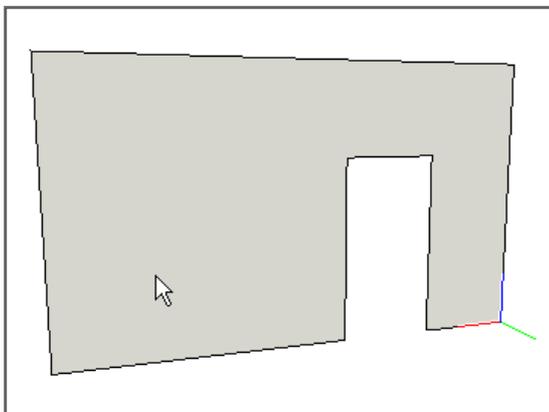
Position the grid cursor in the Zones window on a field of the wanted zone (e.g. zone 1, “Exterior”). Click with the left mouse button on the wall in the Image window. The figures below show the result in the Image window (the wall colour has changed from grey into blue) and the Walls window.



No.	Show	Wall Type	From Zone	To Zone	hg1 [W/m ² K]	hc1 [W/m ² K]	hg2 [W/m ² K]	hc2 [W/m ² K]	Area [m ²]	Weight [kg]
1	YES	External Wall	Exterior		25.0				13.00	4568

Choose *Image > Rotate* or F3, and drag the mouse in the Image window to rotate the wall until the other side of the wall is visible (which is still unpainted, because zone painting only affects only one wall side).

Position the grid cursor in the Zones window on a field of the second zone (“Interior”). Now paint the other wall side using this new zone (press F2 and click on the wall).



No.	Show	Wall Type	From Zone	To Zone	hg1 [W/m ² K]	hc1 [W/m ² K]	hg2 [W/m ² K]	hc2 [W/m ² K]	Area [m ²]	Weight [kg]
1	YES	External Wall	Exterior	Interior	25.0		25.0		13.00	4568

Edit the surface heat transfer coefficients in the Walls window, where needed.

No.	Show	Wall Type	From Zone	To Zone	hg1 [W/m²K]	hc1 [W/m²K]	hg2 [W/m²K]	hc2 [W/m²K]	Area [m²]	Weight [kg]
1	YES	External Wall	Exterior	Interior	25.0		7.7		13.00	4568

Important remark

Check the position of the zones in the fields “From Zone” and “To Zone” which must be compatible to the layer sequence in the wall type file (cf. section F.1): the “from” zone must be at side 1 in the wall type editor (i.e. before layer 1), while the “to” zone must be at side 2 (i.e. after the last layer). In the example above, this is OK and nothing has to be done.

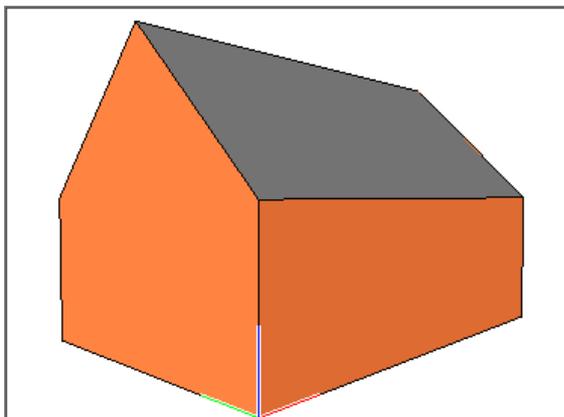
If necessary switch the zones “From Zone” and “To Zone” using the command *Walls > Reverse Zones* or the shortcut key F7 (cf. section C.3).

The solar zone (always zone 1 in the Zones window; cf. section C.2) must always be in the field “From Zone” (never in the field “To Zone”). That is the reason why the layers of wall types of external walls must always be ordered from the outside of the building to the inside (cf. section F.1). (A wall with both sides at the outside is only considered as sun obstacle to other walls, but cannot receive solar radiation in the solar processor.)

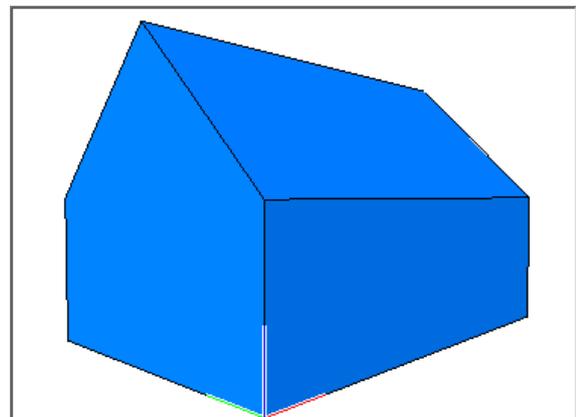
B.7. Looking inside a closed zone

When all walls around a closed (or internal) zone are drawn, all wall types can be painted, as well as all zones at the exterior side of the walls. But painting the internal zone is not possible viewing from the outside. The trick is either to make some walls temporarily invisible from the Walls window (or the Wall Types window), or maybe better to make the exterior zone temporarily invisible from the Zones window.

The figures below show a simple building painted using the wall types (at the left) and painted using the exterior zone (at the right).

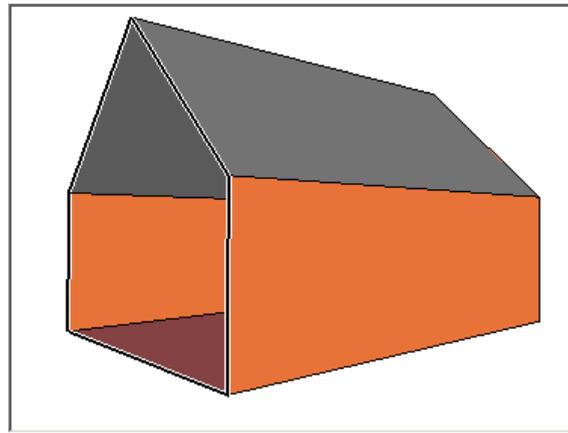
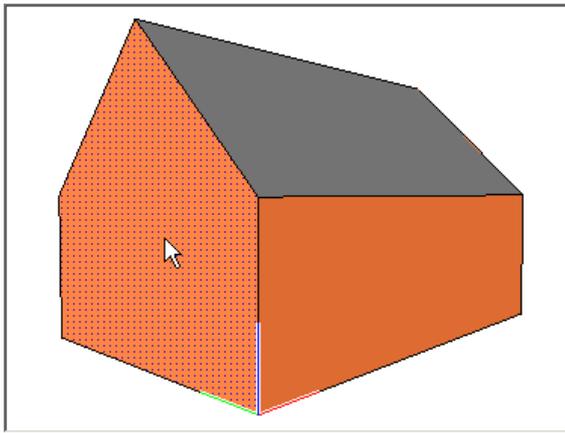


No.	Name	Show	Thickness [cm]	Weight [kg/m²]
1	External Wall	YES	34.5	351.3
2	Floor	YES	26.0	450.2
3	Roof	YES	24.6	52.7



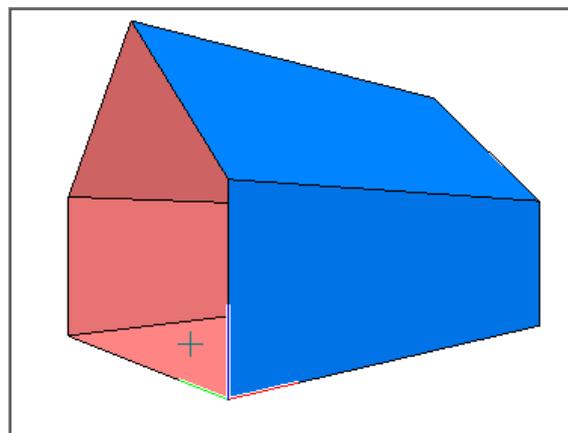
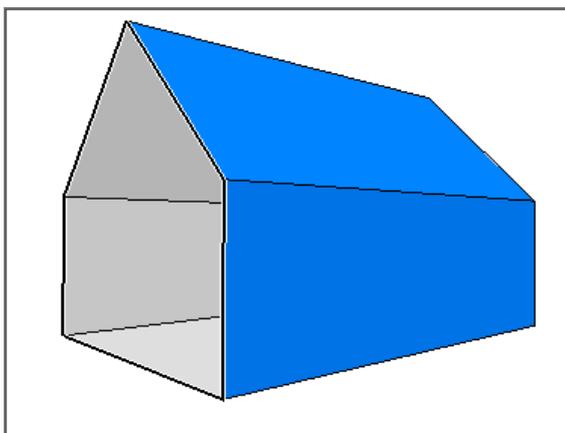
No.	Name	Show	Volume [m³]	p [kg/m³]	Weight [kg]	c [J/kgK]	Rad.
1	Exterior	YES		1.2			1000.0
2	Interior	YES		1.2			1000.0
3	Ground	YES		1.2			1000.0

Select e.g. the left wall from the Image window (figure below left), and make it invisible in the Walls window (by changing the “Show” field from YES into NO; result in figure below right).



No.	Show	Wall Type	From Zone	To Zone	hg1 [W/m²K]	hc1 [W/m²K]	hg2 [W/m²K]	hc2 [W/m²K]	Area [m²]	Weight [kg]
1	NO	External Wall	Exterior		25.0				48.00	16865
2	YES	External Wall	Exterior		25.0				48.00	16865
3	YES	Roof	Exterior		25.0				67.88	3577
4	YES	Floor	Ground		25.0				96.00	43219

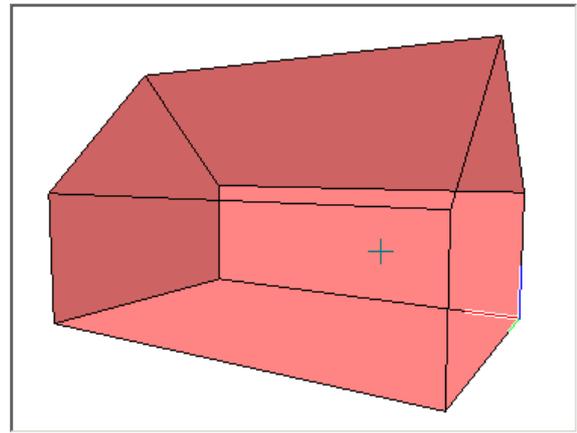
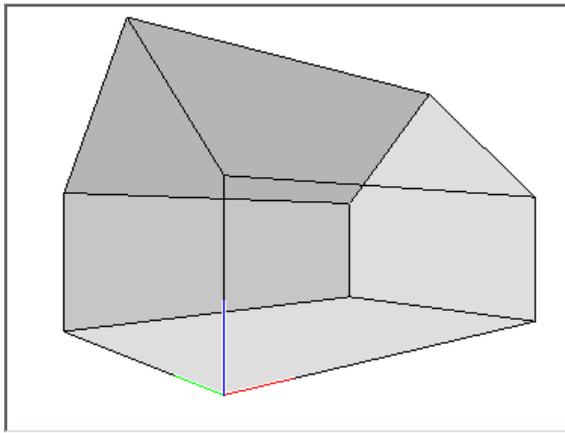
Now the interior zone can be painted on the interior wall surfaces (after clicking F2).
 A disadvantage of this method is that the interior wall surface of the original invisible wall cannot be painted directly. To that end another wall needs to be made (temporarily) invisible, while the first wall needs to be made visible again.



Another (more elegant) possibility to paint the wall surfaces of the interior zone is to switch the visibility status of the exterior zone (making it invisible) to view the walls behind this exterior zone (cf. figures below left). The building can be rotated (press F3 and drag) and all interior wall surfaces can be painted (press F2 and click on the wall faces; cf. figures below right).

No.	Name	Show	Volume [m³]	p [kg/m³]	Weight [kg]	c [J/kgK]	Rad.
1	Exterior	NO		1.2		1000.0	
2	Interior	YES		1.2		1000.0	
3	Ground	YES		1.2		1000.0	

No.	Name	Show	Volume [m³]	p [kg/m³]	Weight [kg]	c [J/kgK]	Rad.
1	Exterior	NO		1.2		1000.0	
2	Interior	YES		1.2		1000.0	
3	Ground	YES		1.2		1000.0	



In general, by switching the visibility status of zones, walls and/or wall types, any wall surface can be made visible and painted.

B.8. Definition of zone volumes

When a zone, defined as the union of all regions at one side of (adjacent) walls, is surrounded entirely by these walls, then the volume of this (internal) zone is automatically calculated and displayed in the Zones window. The volume corresponding to half the wall thickness of all surrounding walls are subtracted from the geometrical volume derived from the flat wall faces. The (smaller) errors at the connection lines between the adjacent walls are not taken into account.

No.	Name	Show	Volume [m ³]	p [kg/m ³]	Weight [kg]	c [J/kgK]	Rad.
1	Exterior	NO		1.2		1000.0	
2	Interior	YES	522.0	1.2	626.4	1000.0	YES
3	Ground	YES		1.2		1000.0	

Remark

When the zone volume is not reported in the Zones window, though the zone seems to be well surrounded by walls in the Image window, this is due to the fact that some of these surrounding walls are not uniquely, but doubly defined (which cannot be noticed in the Image window). Try to identify those double walls (via scrolling through the Walls window) and delete them (via selection in the Image window and pressing the <Delete> key).

Reversely, when the zone volume is reported in the Zones window, this means that the surrounded walls are uniquely defined.

B.9. Single selection of a line, diagonal or wall

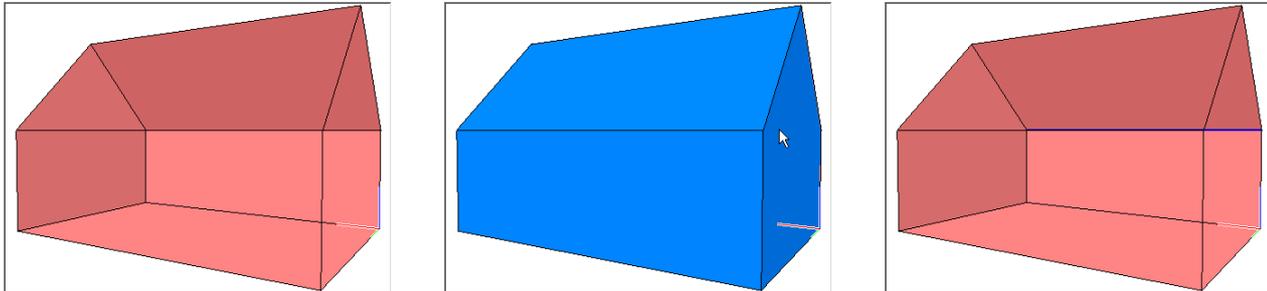
In select mode (*Image* > *Select* or F1) a line, diagonal or wall can be selected by clicking on it with the left mouse button in the Image window. A selected line or diagonal gets a blue colour (cf. section B.2). A selected wall gets a blue dot pattern (cf. example figures in section B.2 and section B.7).

Sometimes the desired wall is not selected after the left mouse button click. This is because an invisible line behind that wall is selected instead (and line selection has priority over wall selection). The following example shows this phenomenon.

Rotate the little building (with exterior zone made invisible) of section B.7 until the top lines of the front and back walls overlap one another (cf. figure below left). Make the exterior zone visible again (by switching the “Show” status to “YES” in the Zones window). In select mode (F1) click

the left mouse button on the right side wall with the mouse cursor in the prolongation of the front wall top line (cf. figure below middle). After the mouse click the right side wall is not selected (as would be expected). Instead the top line of the back wall is selected, which is hidden behind the right side wall.

When the exterior zone is made invisible again, this is made evident by revealing the selected line (cf. figure below right).



The solution to this problem is to move the mouse cursor and click the left mouse button again until the desired wall is finally selected. Since at most one object can be selected at any time (when the <Shift> key is not used simultaneously), then there are no hidden selections.

To assure there are no hidden selections or to unselect a selected line or wall, click with the mouse outside of the object.

B.10. Multiple selection of different lines, diagonals and walls

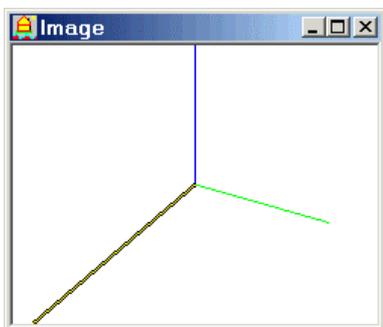
In select mode (F1) several lines, diagonals and walls can be selected, as long as the <Shift> key is held down. When a selected item is clicked again (while the <Shift> key is held down), this item is deselected.

Because also invisible lines (and diagonals) can unintentionally be added to the selection, as explained in the previous paragraph, the option of multiple selection should be used with caution.

Selected items can be deleted (*Geometry* > *Delete* or shortcut key <Delete>) or moved (*Geometry* > *Move* or shortcut key F8) using the displacement defined in the Drawing Vector window.

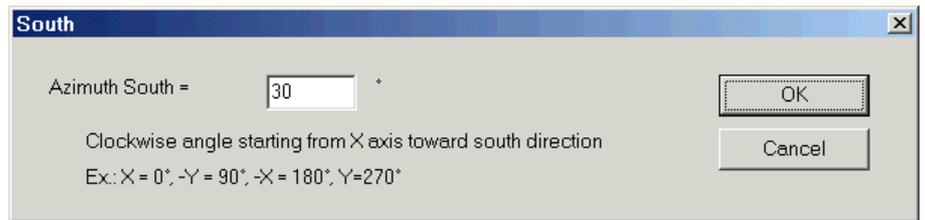
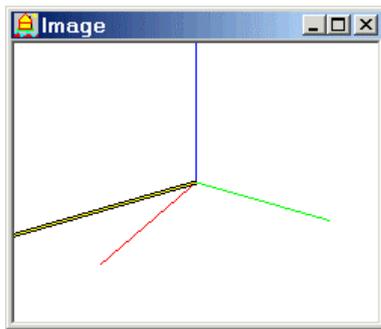
B.11. South direction

The south direction can be viewed using the command *View* > *South* (which acts as a toggle). It is shown using a thin yellow line on a black thicker line, starting from the crosspoint of the red, green and blue coordinate axes.



By default the south direction coincides with the red axis (= X axis). The orientation can be modified using the command *Settings* > *South...*

Only the horizontal angle (= azimuth) in XY (= horizon plane) can be set.

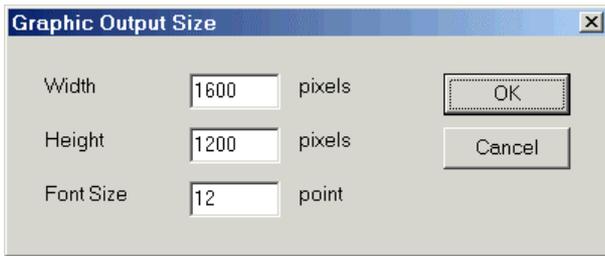


B.12. Viewpoint

Select	F1
Paint	F2
Unpaint	Ctrl+F2
✓ Rotate	F3
Pan	Ctrl+F3
Zoom Window	Ctrl+W
Zoom In	Ctrl+I
Zoom Out	Ctrl+U
Zoom Total	Ctrl+T
Previous View	Ctrl+E
Save Image...	

The view of the object in the Image window can be altered by selecting a view mode in the Image submenu and mouse dragging. The active view mode (either “Rotate”, “Pan”, “Zoom Window” or “Zoom In”) is checked in the Image submenu.

- *Image > Rotate*
Enters rotate mode. Mouse dragging or pressing arrow keys (left, right, up, down, with Image window active) rotate the object.
- *Image > Pan*
Enters pan mode (only possible when the current view is already zoomed in). Mouse dragging or pressing arrow keys (with Image window active) moves the object parallel to the projection plane.
- *Image > Zoom Window*
Enters “zoom window” mode. This allows to draw a zoom rectangle using the mouse in the Image window, which defines the borders of a zoomed view.
Press the <Esc> key to cancel the current zoom rectangle (before releasing the left mouse button).
- *Image > Zoom In*
Enters “zoom in” mode. A following click using the left mouse button in the Image window defines the centre point of the zoomed view. The zoom factor is 75 %.
- *Image > Zoom Out*
Zooms out using a zoom factor of 133 % (or restores the total zoom, when zoomed out enough).
- *Image > Zoom Total*
Shows total object.
- *Image > Previous View*
Shows the previous zoom view.
- *Image > Save Image...*
Saves current image as PNG file.
The image resolution is defined in the dialog opened with *Settings > Graphic Output Size...*



B.13. Calculate view factors

At the end of the geometric input, check the following items:

In the Zones window:

- The first zone (= zone no. 1) must always be the solar zone.
- For each interior zone the volume is shown (which means that all surrounding walls are given and there are no double wall definitions).
- For each interior zone the radiation parameter (column “Rad.”) is set to YES, when infrared radiation using view factors should be calculated.

In the Walls window:

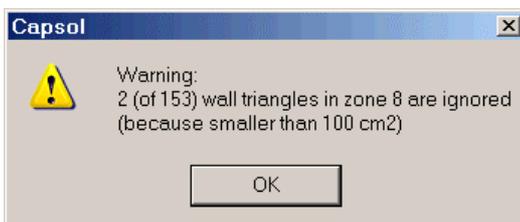
- Each wall is attributed to a wall type.
Also walls of the surroundings of the building, that make up the skyline, are preferably linked to a separate (dummy) wall type, because this allows to quickly hide or show them in the Image window by swapping the “Show” status of this wall type in the Wall Types window.
- The sequence “from zone” “to zone” must correspond to the layer sequence in the wall type definition (cf. section B.6).

View factors are calculated out of the wall triangulation data, and are used in the infrared radiation heat transfer between wall surfaces in interior zones and the distribution of diffuse solar radiation to internal wall surfaces.

For the solar zone the view factors to the sky are calculated out of the wall triangulation data. These sky view factors estimate the fraction of the open sky compared to the global external outlook. Sky view factors are used to calculate the incident diffuse solar irradiation on external walls.

The view factor calculation is based on the triangulations created for the definition of walls (cf. sections B.2 up to B.4). Triangles smaller than 1 dm² are ignored. Large triangles (with a side larger than 1 m) are recursively split. The view factor between each pair of elementary triangles within the same zone are calculated from the surface normal vectors and the line connecting the triangle centres. The view factor equals 0 if the connection line between both centres is obstructed by other wall triangles (visibility check). The elementary view factors are totalled for each wall side (calculating the integral of view factors for all elementary triangles belonging to the same wall).

The view factor calculation is started using the command *Calc > Calc View Factors*.



When there are too many triangles bordering a zone, the calculation fails and an error message is shown.

Warnings are displayed for each zone having small wall triangles, which are ignored (cf. figure at the left). After clicking OK, the view factor calculation continues.

The view factors are saved in a .vwf file (with same file name as CAPSOL data file). This .vwf file is a text file, with the following syntax:

For view factors between wall surfaces (within interior zone): “view= $Z Ic Jc V$ ”, with:
 Z = zone number (of interior zone),
 I = wall number (of the view factor source),
 J = wall number (of the view factor receiver),
 c = letter “a” (for first side of wall) or “b” (for second side of wall),
 V = view factor (between 0.005 and 1; if smaller than 0.005, the view factor is neglected).

For view factors to the sky: “skyv= $I V$ ”, with:
 I = wall number (of the view factor source),
 V = view factor to the open sky (between 0 and 1).

A view factor file can be read in CAPSOL using the command *Calc > Read View Factors....*. Reading view factors only succeeds if the geometry has not been modified after the view factor file was created (using *Calc > Calc View Factors*). Establishing the view factors (by either *Calc > Calc View Factors* or *Calc > Read View Factors...*) is necessary before starting the calculation (*Calc > Calc Start*, cf. section D.3).

CHAPTER C THERMAL DATA INPUT

C.1. Wall Types window

The Wall Types window (activated using *Edit > Wall Types*) contains all wall types that can be attributed to walls (cf. section B.5).

No.	Name	Show	Thickness [cm]	Weight [kg/m ²]
1	External Wall	YES	34.5	351.3
2	Floor	YES	26.0	450.2
3	Roof	YES	24.6	52.7

Insert	Ins
Delete	Ctrl+Del
Move	
Stop Move	
Show All	
Show Only Current	
Save Values...	

Per wall type there are the following column fields:

- Sequence number.
- Colour value, which can be edited (press <Enter> when this field is active, or double click with the left mouse button).
- Name: file name of wall type file (with file extension .cwt), which must be present in the same directory as the CAPSOL data file.
Press <Enter> (when this field is active) to select the .cwt file in the File Open dialog box.
The wall type files (containing the wall layers and their thermal properties) can be edited using the Wall Type Editor (cf. Chapter F).
- Show: show ("YES") or hide ("NO") in the Image window all walls having this wall type.
- Thickness in cm (not editable).
- Weight in kg/m² (not editable).

The following menu commands are available from the submenu *Wall Types* (cf. figure above right):

- *Wall Types > Insert*
Insert a new wall type after the current one (cf. figure below left).

No.	Name	Show	Thickness [cm]	Weight [kg/m ²]
1	External Wall	YES	34.5	351.3
2		YES	0.0	0.0
3	Floor	YES	26.0	450.2
4	Roof	YES	24.6	52.7

No.	Name	Show	Thickness [cm]	Weight [kg/m ²]
1	External Wall	YES	34.5	351.3
2	Floor	YES	26.0	450.2
3	Roof	YES	24.6	52.7

- *Wall Types > Delete*
Delete the current wall type.
This command is disabled if the current wall type is attributed to any wall.
In that case first unpaint the walls in question (using Ctrl+F2) or paint these walls using a different wall type.
- *Wall Types > Move*
Highlight the current wall type (cf. figure above right), which then can be moved up or down using the arrow keys or a mouse click on a different row.
- *Wall Types > Stop Move*
Stop "move" mode.

- *Wall Types > Show All*
Set “show = YES” for all wall types.
- *Wall Types > Show Only Current*
Set “show = YES” for the current wall type, and “show = NO” for all other wall types.
- *Wall Types > Save Values...*
Save the properties of all wall types in a text file.

C.2. Zones window

The Zones window (activated with *Edit > Zones*) contains all zones that can be attributed to wall sides (cf. section B.6).

The first zone in the list of zones must be the solar zone (if solar radiation is involved).

No.	Name	Show	Volume [m ³]	ρ [kg/m ³]	Weight [kg]	c [J/kgK]	Rad.	Fixed Temp.	Temp. [°C]	Power [W]	Flux [W/m ²]
1	Exterior	YES		1.2		1000.0			T01		0.0
2	Interior	YES	522.0	1.2	626.4	1000.0	YES	NO		0.0	
3	Ground	YES		2000.0		835.0			10.2		0.0

Per zone there are the following column fields:

- Sequence number.
- Colour value, which can be edited (press <Enter> when this field is active, or double click with the left mouse button).
- Name.
- Show: show (“YES”) or hide (“NO”) the current zone in the Image window.
- Volume (not editable): volume in m³ of interior zone (entirely surrounded by walls, but without double redundant wall definitions, cf. section B.8).
The volume corresponding to half the wall thickness of all surrounding walls are subtracted from the geometrical volume derived from the flat wall face positions. The (smaller) errors at the line connections between the adjacent walls are neglected.
- Material density ρ in kg/m³.
- Weight in kg (not editable).
- Specific heat c in J/(kg.K).
- Radiation: YES or NO (only enabled for interior zones).
If “YES”, infrared radiation using view factors is considered in the current (interior) zone.
If “NO” (or blank field for exterior zone), the heat transfer between the current zone and the surrounding walls is convective (using global surface heat transfer coefficients, as defined in the Walls window).
- Fixed temperature: YES or NO (only enabled for interior zones).
- Temperature: fixed value (in °C) or reference to temperature function (T01 up to T99, cf. section C.9).
- Power: internal power released in zone convection node.
Fixed value (in W) or reference to power function (P01 up to P99, cf. section C.9).
- Flux: imposed on all wall surfaces bordering the current zone.
Fixed value (in W/m²) or reference to infrared flux function (I01 or I99, cf. section C.9).

The following menu commands are available from the submenu *Zones*:

- *Zones > Insert*: insert a new zone after the current one.
- *Zones > Delete*: delete the current zone.
This command is disabled if the current zone is attributed to any wall side.

In that case first unpaint the wall sides in question (using Ctrl+F2) or paint these wall sides using a different zone.

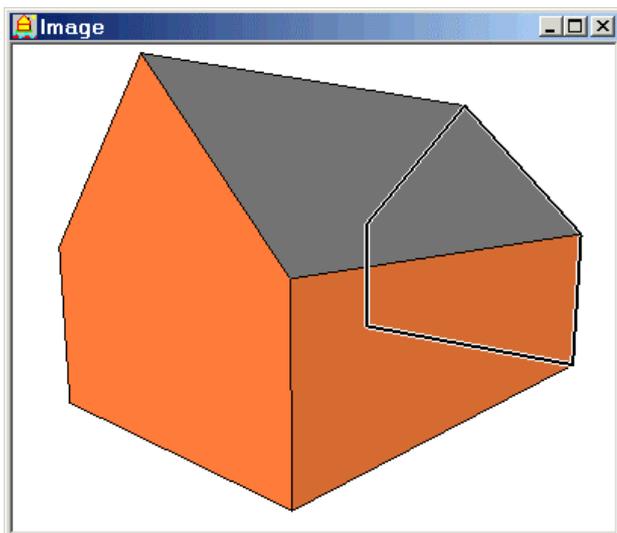
- *Zones > Move*: highlight the current zone, which then can be moved up or down using the arrow keys or a mouse click on a different zone.
- *Zones > Stop Move*: stop “move” mode.
- *Zones > Show All*: set “show = YES” for all zones.
- *Zones > Show Only Current*: set “show = YES” for the current zone, and “show = NO” for all other zones.
- *Zones > Save Values...*: save the properties of all zones in a text file.

C.3. Walls window

The walls in the Walls window (activated using *Edit > Walls*) are created when drawing the geometry (cf. section B.2).

No.	Show	Wall Type	From Zone	To Zone	hg1 [W/m ² K]	hc1 [W/m ² K]	hg2 [W/m ² K]	hc2 [W/m ² K]	Area [m ²]	Weight [kg]
1	YES	External Wall	Exterior	Interior	25.0			2.5	48.00	16865
2	YES	External Wall	Exterior	Interior	25.0			2.5	48.00	16865
3	YES	Roof	Exterior	Interior	25.0			2.5	67.88	3577
4	YES	Floor	Ground	Interior	25.0			2.5	96.00	43219
5	YES	Roof	Exterior	Interior	25.0			2.5	67.88	3577

The outline of the current wall in the Walls window is highlighted in the Image window (cf. figure below left).



Reverse Zones F7
Global for Zone

Show All

Save Values...

Per wall there are the following fields:

- Sequence number.
- Show: show (“YES”) or hide (“NO”) the current wall in the Image window.
- Wall type: set by painting the wall type in the Image window (cf. section B.5).
- From zone (= zone 1): zone at one side of the wall, before the first layer of the wall type. The sequence of the wall type layers is visible in the Wall Type Editor (cf. section F.1). A zone is attributed to a wall side by painting in the Image window (cf. section B.6).
- To zone (= zone 2): zone at other side of the wall, after the last layer of the wall type.

- hg1 [W/(m².K)]: global surface heat transfer coefficient at first wall side (adjacent to zone 1). This field is only editable if zone 1 is an exterior zone (volume field is empty in Zones window) or an interior zone without infrared radiation (“Rad.” = NO in Zones window).
- hc1 [W/(m².K)]: convective heat transfer coefficient at first wall side (adjacent to zone 1). This field is only editable if zone 1 is an interior zone with infrared radiation (“Rad.” = YES in Zones window).
- hg2 [W/(m².K)]: global surface heat transfer coefficient at second wall side (adjacent to zone 2). This field is only editable if zone 2 is an exterior zone (volume field is empty in Zones window) or an interior zone without infrared radiation (“Rad.” = NO in Zones window).
- hc2 [W/(m².K)]: convective heat transfer coefficient at second wall side (adjacent to zone 2). This field is only editable if zone 2 is an interior zone with infrared radiation (“Rad.” = YES in Zones window).
- Area [m²]: area of wall triangulation (cf. section B.2).
- Weight [kg]: product of weight per unit of area of wall type (in Wall Types window) and area.

When a wall is lying between a solar zone (which must be the first zone in the Zones window) and another (internal) zone, then the solar zone must be situated in the field “From Zone”. The layers in a wall type of an external wall are ordered from the outside of the building toward to the inside (cf. section B.6 and section F.1).

The following menu commands are available from the submenu *Walls* (cf. figure above right):

- *Walls > Reverse Zones* (or shortcut key F7): switch zone 1 (“From Zone”) and zone 2 (“To zone”), so that both zones at either sides of the wall are in line with the layer sequence of the wall type (cf. section B.6).
- *Walls > Global for Zone*: make the current property (hg1, hc1, hg2 or hc2) global to all wall sides in the same zone.
- *Walls > Show All*: set “show = YES” for all walls.
- *Walls > Save Values...*: save the properties of all walls in a text file.

C.4. Zone Ventilation window

The Zone Ventilation window (activated using *Edit > Zone Ventilation*, cf. figure below left) contains all (natural and mechanical) ventilation flows to interior zones (having a defined volume in the Zones window) with unknown temperature. Ventilation flows to zones with fixed temperature must not be defined, because they have no influence on the system of equations.

During the calculation the ventilation balance for every zone (with unknown temperature) is checked: the total incoming ventilation flow should not be lower than the total outgoing ventilation flow (to zones with unknown temperature). The possible positive difference between the total incoming and total outgoing ventilation flows is supposed to leave to a zone with known temperature (which is neutral to the system).

For every ventilation flow in the Zone Ventilation window both zones (source and destination) should have equal material density and specific heat (as defined in the Zones window). This requirement is checked at the start of the calculation.

No.	From	To	Rate [m3/h]	Rate [/h]	Control
1	1 Exterior	2 Interior	513.7	1.0	

Insert	Ins
Delete	Ctrl+Del
Filter From	
Filter To	

Per ventilation flow there are the following fields:

- Sequence number.

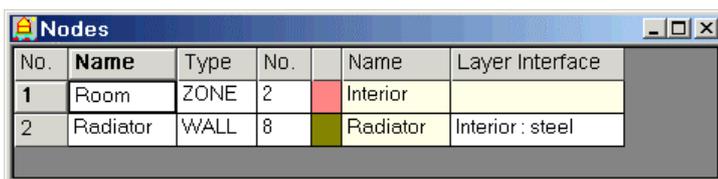
- “From”: zone number of ventilation source (exterior or interior zone).
- “To”: zone number of ventilation destination (which must be an interior zone with unknown temperature).
- “Rate [m³/h]”: ventilation flow rate in m³/h or reference to ventilation function (V01 up to V99, cf. section C.9).
- “Rate [h]” (not editable): number of volume changes (of destination zone) per hour.
- Control: if blank, this ventilation flow is always applied.
If a control sequence number (of a ventilation control, cf. section C.7) is entered, this ventilation flow is only applied when the referred ventilation control is set (i.e. when the condition of this ventilation control is true).

The following menu commands are available from the submenu *Ventilation* (cf. figure above right):

- *Ventilation > Insert*: insert a new ventilation flow after the current one.
- *Ventilation > Delete*: delete the current ventilation flow.
- *Ventilation > Filter From* (toggle): show only the ventilation flows with source zone equal to the source zone of the current ventilation flow.
- *Ventilation > Filter To* (toggle): show only the ventilation flows with destination zone equal to the destination zone of the current ventilation flow.

C.5. Nodes window

The Nodes window (activated using *Edit > Nodes*) contains the nodes in the system of thermal equations that are used as control points referred to in the Conditions window (cf. section C.6) or Controls window (cf. section C.7).



No.	Name	Type	No.	Name	Layer Interface
1	Room	ZONE	2	Interior	
2	Radiator	WALL	8	Radiator	Interior : steel

There are two types of nodes:

- *Zone node*: convection node (with air temperature or fluidum temperature) of a zone, which is connected to the nodes of the surrounding wall surfaces via the convective heat transfer coefficients.
- *Wall node*: wall surface node or internal wall node in the interface between two wall layers.

Per node in the Nodes window there are the following fields:

- Sequence number.
- Name.
- Type: ZONE or WALL.
- Object number: zone number (if type = ZONE) or wall number (if type = WALL).
The next two fields show the colour and name of this zone or wall (copied from the Zones window or Walls window).
- Layer interface (only if type = WALL): toggle button (press <Enter> to pass through the successive wall layer interfaces).

A new node can be inserted using *Edit > Insert*.

An existing node can be deleted using *Edit > Delete*.

C.6. Conditions window

The Conditions window (activated using *Edit > Conditions*) contains the conditions imposed by the controls in the Controls window.

A condition is a logical expression which compares the value of a property to a target value.

The condition is evaluated at each time step during the calculation. The result (true or false) is used to trigger a control.

No.	Name	Type	Prop.	Sensor Node	Ref. Node	Op.	Target	Margin	Prop.	No.	Op.	Prop.	No.	Result
1	Room cold	BASIC	OPTEMP	1	Room	<	21	0.5						

There are two types of conditions:

- Basic condition (type = BASIC): which compares the value of a property (e.g. temperature or solar irradiation) in a node (defined in the Nodes window) to a target value (or target function).
- Composite condition (type = COMPOSITE): which performs a logical operation (“AND”, “OR”, “NOT”) on one or two basic conditions or control results (defined in the Controls window).

Per condition there are the following fields:

- Sequence number.
- Name.
- Type: BASIC or COMPOSITE.

If type = BASIC:

- Property: TEMP (node temperature), OPTEMP (operative temperature of a zone, which is the mean of the air temperature and the radiation temperature of the surrounding wall surfaces), TEMPDIFF (temperature difference) or SOLRAD (total solar irradiation on an external wall surface in W/m²).
- Sensor node: node number in Nodes window, where the property is evaluated.
- Reference node (only if property = TEMPDIFF): node number of second node (which temperature is the subtrahend of the temperature difference) in Nodes window.
- Operand: < (less than) or > (greater than).
- Target: numerical value or (if property = TEMP, OPTEMP or TEMPDIFF) reference to temperature function (T01 up to T99).
- Margin: upward and downward sensitivity with reference to the target value.

For operand <:

if sensor value < target value – margin, then condition result = true;
 else if sensor value > target value + margin, then condition result = false;
 else condition result remains unchanged (same result as for previous time step).

For operand >:

if sensor value > target value + margin, then condition result = true;
 else if sensor value < target value – margin, then condition result = false;
 else condition result remains unchanged (same result as for previous time step).

If type = COMPOSITE:

- Property: CONDIT (condition) or CTRL (control).
- Number: condition sequence number in Conditions window (if property = CONDIT) or control sequence number in Controls window (if property = CTRL).
- Operand: AND, OR (inclusive disjunction) or NOT.

For both types (BASIC and COMPOSITE):

- Result: condition result at current time step (TRUE or FALSE, only displayed during a calculation).
If result = INVALID, then there is an error in one or more condition parameters.

A new condition can be inserted using *Edit > Insert*.
An existing condition can be deleted using *Edit > Delete*.

C.7. Controls window

The Controls window (activated using *Edit > Controls*) contains the controls of the system.

No.	Name	Condit.	Action	Node	Pmax [W]	τ [min]	Wall	Wall Type	New	Wall Type	Time On [min]	Time Off [min]	Result		
1	Radiator heating	1	Room cold	HEATING	2	Radiator	10000	10					0	0	

There are three types of controls:

- Power (heating when positive, or cooling when negative) released in a node (defined in the Nodes window) with an exponential course:

$$P_t = P_{max} \times \left(1 - e^{-\frac{t}{\tau}} \right)$$

with:

P_t = power at time t (t = 0 when starting the power release),

P_{max} = maximum power,

τ = time constant (time required to release 63.2 % of the maximum power).

If the power is switched off, there is an exponential decay (using the same time constant).

- Extra ventilation flow(s) (defined in the Ventilation window with parameter “Control” = control sequence number, cf. section C.4).

These extra ventilation flows are activated when the result of the corresponding condition is true.

- Sunshade control applied to a wall, implemented by using a different wall type with modified thermal properties for the wall layers (solar reflection, transmission, absorption, infrared emissivity, thermal conductivity).

The original wall type and the new wall type must generate the same number of system nodes with unchanged thermal capacities (due to the law of conservation of energy). Both wall types must have the same number of layers, and per layer the same layer type (“normal” or “gas”), thickness, density (ρ) and specific heat (c).

Per control there are the following fields:

- Sequence number.
- Name.
- Condition number (in the Conditions window), which when true activates the control (control result = ON), and when false deactivates the control (control result = OFF).
- Action: HEATING, COOLING, VENTIL or SUNSHADE.

If action = HEATING or COOLING (i.e. power control):

- Node: node number in Nodes window, in which the control power is released.
- Pmax [W]: maximum power.
- τ [min]: time constant of exponential power release in minutes.

If action = SUNSHADE:

- Wall: wall number in Walls window, on which the sunshade control is applied.
- Wall type (not editable): colour and name of (original) wall type of wall.

- New wall type: wall type number in Wall Types window of new wall type (compatible to the original one) adopted to the wall as sunshade.
 - Next two fields (not editable): colour and name of new wall type.
- If action = VENTIL: no other fields must be defined in the Controls window. The corresponding ventilation flows are defined in the Ventilation window (cf. section C.4).
- For all controls (HEATING, COOLING, VENTIL or SUNSHADE):
- Time On [min]: minimum time duration in minutes that the control remains active once switched on.
 - Time Off [min]: minimum time duration in minutes that the control remains deactivated once switched off.
 - Result: control status at current time step (ON or OFF, only displayed during a calculation).

A new control can be inserted using *Edit > Insert*.

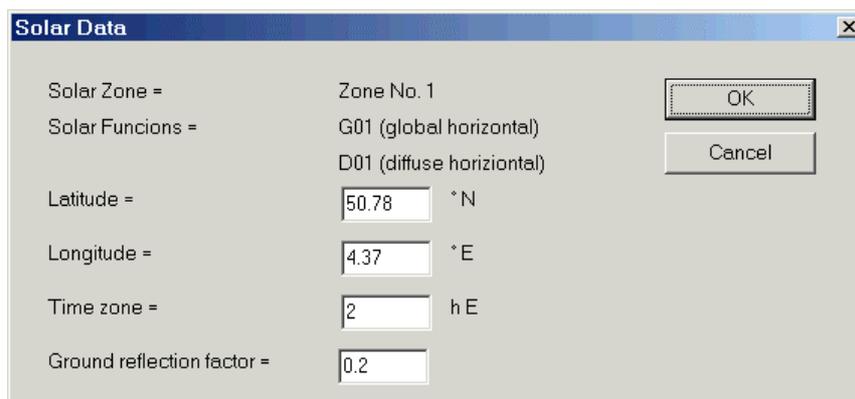
An existing control can be deleted using *Edit > Delete*.

C.8. Solar data

The command *Edit > Solar Data...* opens the Solar Data dialog box (cf. figure below).

The solar zone must be the first zone in the Zones window.

The solar radiation must be defined by the function references G01 (global solar radiation on a horizontal face) and D01 (diffuse solar radiation on a horizontal face) in the Functions window.



The following parameters are defined:

- Latitude: geographical latitude (positive to the north).
For Uccle (Brussels): 50.78°N.
- Longitude: geographical longitude (from the meridian of Greenwich, positive to the east).
For Uccle (Brussels): 4.37°E.
- Time zone: offset from UTC (Coordinated Universal Time), positive to the east.
For Uccle (Brussels): 1 h (winter time) or 2 h (summer time).
- Ground reflection factor: (diffuse) reflection factor of building surroundings (supposed as an infinite horizontal face without obstructions; cf. section D.5).
Normal value: 0.2. Very reflective ground (e.g. snow): 0.8 to 0.9.

C.9. Functions window

The Functions window (activated using *Edit > Functions*) contains function references used in other windows.

No.	Ref.	Type	Filename	Prm.1	Prm.2	Prm.3	Prm.4	Prm.5	Prm.6
1	T01	FILE	UCL	77					
2	G01	FILE	UCL	77					
3	D01	FILE	UCL	77					

All functions are time functions.

There are several types of functions:

- Internal functions (type STEP0, STEP1, STEP2, SINE and SINPOS), which are built-in program functions (cf. figures below).
- External functions (type FILE), defined in external files (cf. Chapter G).
The file extension depends on the function variable, identified by the first letter of the function reference:
 - .fte: temperature function [$^{\circ}\text{C}$] with function reference T## (with # a digit).
 - .ffh: power function [W] with function reference P##.
 - .fir: infrared radiation function [W/m^2] with function reference I##.
 - .fsg: global solar radiation on a horizontal face [W/m^2] with function reference G01.
 - .fsd: diffuse solar radiation on a horizontal face [W/m^2] with function reference D01.
 - .fvr: ventilation flow function [m^3/h] with function reference V##.

Per function there are the following fields in the Function window:

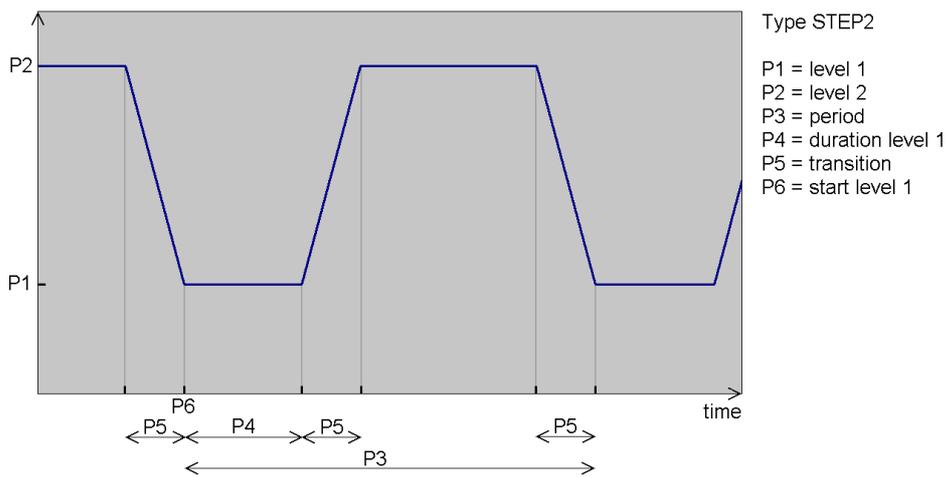
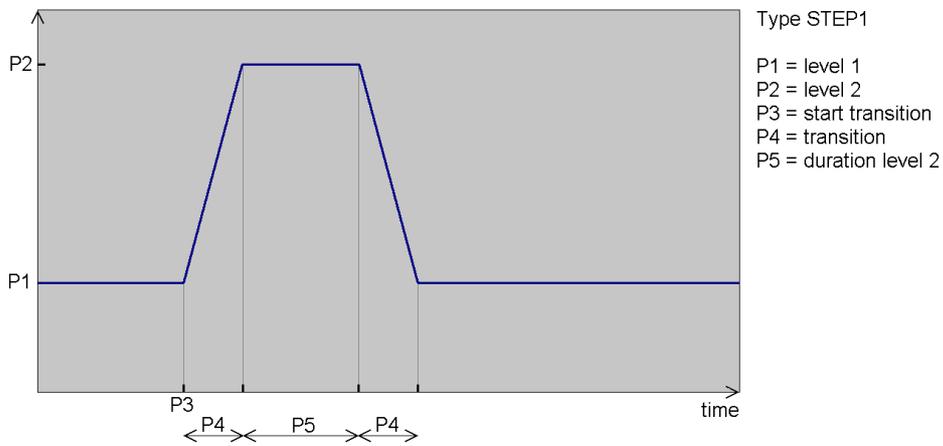
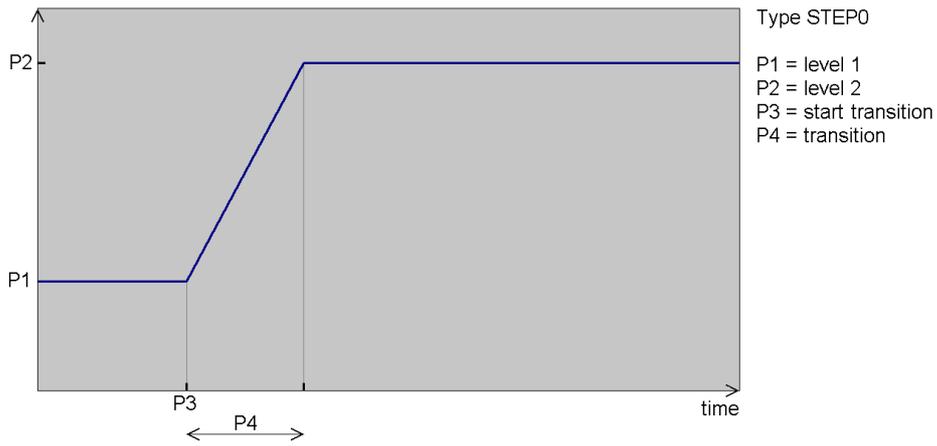
- Sequence number.
- Function reference: T##, P##, I##, G01, D01 or V##, with ## = 01 up to 99.
- Function type: toggle with values FILE, STEP0, STEP1, STEP2, SINE and SINPOS.
- File name (if type = FILE) of file selected from File Open dialog box, in the same directory as the CAPSOL data file (because only the file name of the function file, and not its directory, is stored in this CAPSOL data file).
- Parameters 1 to 6: meaning dependent on the function type (cf. below).

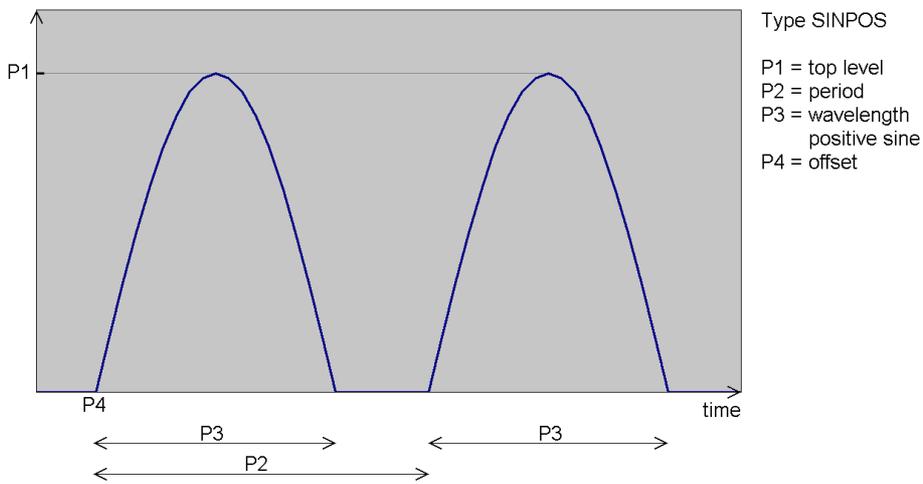
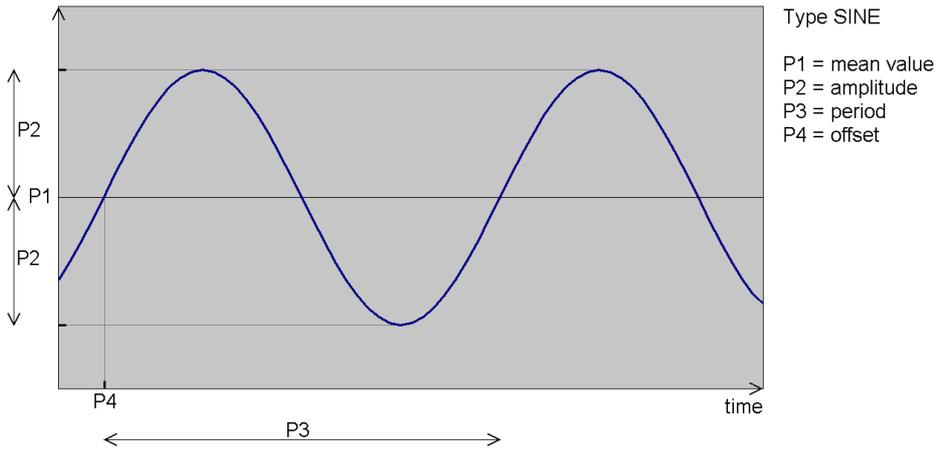
The current function can be visualised using the menu command *Chart > Function* in the Chart window (cf. section E.2).

A file function (type = FILE) can be translated (i.e. shifted in time) using a time offset, expressed in minutes, via parameter 1 (column “Prm. 1”) in the Functions window.

This is useful to align the climate functions (temperature, global and diffuse solar radiation on a horizontal face) with e.g. the time of sunrise or sunset displayed in the status bar from the calculation start or end time in the Time window (cf. section D.1).

The figures below show the meaning of the different parameters P1 up to P6 (in the columns “Prm. 1” up to “Prm. 6” in the Functions window) for the types STEP0, STEP1, STEP2, SINE and SINPOS.





A new function can be inserted using *Edit > Insert*.

A function (if not referred to in another window) can be deleted using *Edit > Delete*.

CHAPTER D CALCULATION

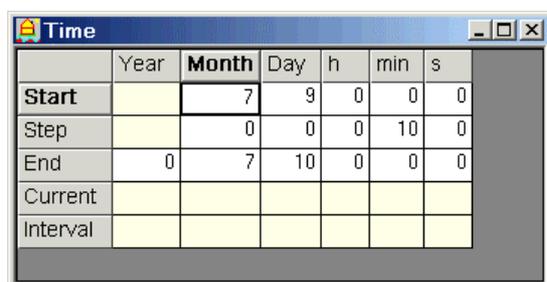
D.1. Time window

The Time window (activated using *Edit > Time*, cf. figure below left) contains the time data for the dynamic calculation:

- Start time.
- Calculation time step.
- End time.
- Current time (once the calculation is started).
- Time interval (once the calculation is started).

When the current input cell (surrounded by thick lines) is on the start time, end time or current time, the status bar contains the times of sunrise and sunset (cf. figure below right).

If the sun is visible above the horizon, also the solar azimuth (negative at east, 0° at south, positive at west) and the solar elevation is given.



	Year	Month	Day	h	min	s
Start		7	9	0	0	0
Step		0	0	0	10	0
End	0	7	10	0	0	0
Current						
Interval						

Sunrise: 05h45 Sunset: 21h49

Solar azimuth: -46° Solar elevation: 55° Sunrise: 05h45 Sunset: 21h49

The absolute times (start, end and current time) in the Time window are standard times.

The relation between standard times and mean solar times depend on the longitude and time zone, defined in the Solar Data dialog box.

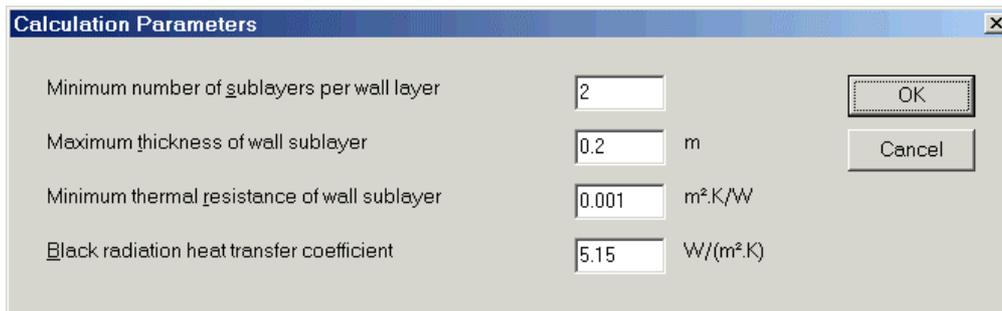
For the absolute times the column fields are:

- Year: number of years since the start time (start year = 0).
- Month: 1 (for January) up to 12 (for December).
- Day: from 1 up to 31.
- Hour (h): from 0 up to 23.
- Minute (min): from 0 up to 59.
- Second (s): from 0 up to 59.

For the relative times (time step and interval) 1 month corresponds to 30 days.

D.2. Calculation parameters

The Calculation Parameters dialog box is opened using *Settings > Calculation Parameters....*



There are four calculation parameters:

- Minimum number of sublayers per wall layer.
- Maximum thickness of wall sublayer.
- Minimum thermal resistance of wall sublayer.
- Black radiation heat transfer coefficient.

Each wall material layer (type NORMAL in wall type editor; cf. section F.2) is subdivided in a number of sublayers of equal thickness (and having the same thermal properties as the layer).

The number of sublayers must be at least the value given by the first calculation parameter.

However if the thickness of the sublayers is still greater than the value given by the second calculation parameter, then the number of sublayers is sufficiently increased.

A gas layer (type “GAS” in the wall type file; cf. section F.3) is not subdivided into sublayers.

Within each wall the system nodes are located in the interfaces between the successive sublayers.

If the number of sublayers is increased, the number of system nodes also grows, and the quality of the dynamic calculation improves, but the calculation time prolongs.

For the calculation stability (expressed by the Fourier number of the dynamic system) the thermal resistance of each wall sublayer should be large enough.

If it is smaller than the value of the third calculation parameter, it is replaced by this parameter in the system setup to make the system more stable.

The radiation within the zones is linear with a constant black radiation heat transfer coefficient (h_{rb}), given as fourth calculation parameter. The value is based on the estimated mean temperature (θ_m in °C) over all zones with radiation: $h_{rb} = 4 \cdot \sigma \cdot T_m^3$ with $\sigma = 5.67 \cdot 10^{-8} \text{ W}/(\text{m}^2 \cdot \text{K}^4)$ (Stefan-

Boltzmann constant) and $T_m = \theta_m + 273.15$.

D.3. Start calculation

Calc View Factors	
Read View Factors	
Start Calc	Shift+S
Next Step	Shift+N
Next Interval	Shift+I
Run Calc	Shift+R
Edit BCs	Shift+E
Close Calc	Shift+O
Save Step Solution...	
Read Step Solution...	

After establishing the view factors between all wall surfaces (cf. section B.13), the calculation is started using the menu command *Calc > Start Calc* (to get steady state start values) or *Calc > Read Step Solution...* (to read a previous saved solution file).

The current CAPSOL data are first saved in a CAPSOL data file.

The system of nodes is set up. Each wall is considered as a linear list of nodes, which number depends on the layers in the wall type (cf. section F.1) and the sublayer calculation parameters (cf.

section D.2). For each wall surface adjacent to a zone with radiation, a black radiation node is added. For each zone with unknown temperature a zone convection node is added. The thermal system is set up as a system of linear equations with minimised bandwidth and with coefficients that may modify from one time step to the next time step.

Memory space is allocated for the system and for the solutions (node temperatures) for all time steps in the time domain, so that it becomes possible during a calculation to rewind to any previous calculated time step, review the solution at that time step and possibly adapt the thermal properties.

The start calculation command (*Calc > Start Calc*) does the memory allocation and system setup (as explained above), then calculates a steady state solution (ignoring the thermal capacities) for the first time step, shows the wall surface temperatures in the Image window, and waits for the next user command.

The read step solution command (*Calc > Read Step Solution...*) does the memory allocation and system setup (as explained above), then initialises the node temperatures from a solution file (with extension .sol), which must have the same number of nodes as the current system. If successful, the wall surface temperatures are shown in the Image window, and the program waits for the next user command.

After a successful *Calc > Start Calc* or *Calc > Read Step Solution...* the Time window is updated (cf. figure below left):

- Editing of the start time, time step and end time is disabled (until the command *Calc > Close Calc* is executed).
- The current (last calculated) time step is shown.
- The time interval can be edited (used by *Calc > Next Interval* or *Output > Next Interval*).

	Year	Month	Day	h	min	s
Start		7	9	0	0	0
Step		0	0	0	10	0
End	0	7	10	0	0	0
Current	0	7	9	0	0	0
Interval	0	0	0	1	0	0

Calc View Factors	
Read View Factors	
Start Calc	Shift+S
Next Step	Shift+N
Next Interval	Shift+I
Run Calc	Shift+R
Edit BCs	Shift+E
Close Calc	Shift+O
Save Step Solution...	
Read Step Solution...	

New thermal properties can be entered in the Walls window (hg1, hc1, hg2, hc2), Zones window (temperature, power, flux) and Zone Ventilation window, which will be used for the next time steps. The other input fields in these input windows are disabled, because they would generate a different system of equations. The editable input fields only change the coefficients of the system of equations.

New wall types for any wall, that are compatible with the original ones, as for a sunshade control (cf. section C.7), can be set for the next time steps by repainting the wall in the Image window (cf. section B.5).

Other commands in the Calc submenu (cf. figure above right) are enabled to continue the dynamic calculation.

D.4. Dynamic calculation steps

The command *Calc > Next Step* calculates one step ahead from the current time step.

The command *Calc > Next Interval* calculates all steps for the next time interval (as defined in the Time window).

The command *Calc > Run Calc* calculates all remaining time steps until the calculation end time is reached.

The current time in the Time window is adapted continuously after the calculation of each time step.

It is possible to rewind to a previous calculated time step using the commands of the Output submenu.

C <u>urrent Time</u>	Ctrl+Shift+C
N <u>ext Step</u>	Ctrl+Shift+N
N <u>ext Interval</u>	Ctrl+Shift+I

Enter the time of the previous time step as current time in the Time window.

Then choose the command *Output > Current Time* to load the solution for that time step. All input from the input windows (Walls window, Zones window and Zone Ventilation window) is now blocked, because we are viewing previous calculated results in the Image window.

The command *Output > Next Step* loads the solution of the next time step (up to the last calculated time step).

The command *Output > Next Interval* loads the solution of the time step at the next time interval (up to the last calculated time step).

In this way the solutions for every time step of the complete time range can be reviewed (see also section E.1).

At every time step the node temperatures can be saved into a step solution file (with extension .sol), using the command *Calc > Save Step Solution....* The suggested file name in the File Open dialog includes the CAPSOL data file name and the current time.

It is possible to restart the calculation from any previous calculated time step with modified input properties. Use the command *Output > Current Time* to go back to a previous time step (cf. above). Then choose *Calc > Edit BCs*. The solutions of all following time steps are cleared from memory, so that this time step becomes the last calculated time step. As a result new thermal properties can now be entered in the Walls window (hg1, hc1, hg2, hc2), Zones window (temperature, power, flux) and Zone Ventilation window.

New wall types for any wall, that are compatible with the original ones, as for a sunshade control (cf. section C.7), can be painted in the Image window (cf. section B.5).

From the current time step the calculation can then again be continued using the commands *Calc > Next Step*, *Calc > Next Interval* and *Calc > Run Calc*.

The command *Calc > Close Calc* stops the calculation process and frees all calculation memory, except the view factors. (The view factors are freed from memory when the geometry is modified, or the CAPSOL file is closed.)

D.5. Solar processor

Each calculation time step the solar load must be determined.

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). The position of the sun is located by two angular measures: azimuth (horizontal clockwise angle from the south to the sun) and elevation (vertical angle from the horizon to the sun). 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). This means e.g. that the azimuth at 12 a.m. solar mean time fluctuates around 0° (= south).

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 (function references G01 and D01). Usually these climate files contain hourly values. The current values are derived through linear interpolation from the adjacent hourly values. For the first and last daylight hour of the day, the (estimated) times of sunrise and sunset are used for interpolation.

For each external wall between the solar zone and an internal zone the solar irradiation is calculated, which is composed of a direct, a diffuse and a ground reflected component.

For the direct solar irradiation the wall triangles (from the input geometry) are fragmented in smaller parts which receive each maximum 10 W (possible obstructions to the sun not taken into account). A visibility test (for a ray between the centre of this wall part and the sun, and considering possible shading by other walls) decides whether this solar power must be added to the wall external surface node or not.

For the same external wall (between the solar zone and an internal zone) the diffuse solar irradiation in the free field (without considering the surroundings) is calculated using the anisotropic diffuse model developed by Tariq Muneer, which takes into account the orientation, slope, shaded or sunlit condition, overcast and non-overcast condition.

The diffuse solar irradiation in the free field is reduced by the sky visibility factor, which is the ratio of the really open sky to the global sky dome (thus including the surroundings). The sky visibility is calculated in advance (as part of the command *Calc > View Factors*) using a high number of random rays in all directions from the wall surface to the sky, and counting the fraction which is not obstructed by other walls.

The reflected irradiation of the ground to the external wall is calculated using the isotropic diffuse model (i.e. irradiation proportional to the square of the sine of half the wall tilt), the global solar radiation on a horizontal surface and the ground reflection factor (calculation parameter defined in *Settings > Calculation Parameters...*). The ground reflected radiation on a vertical surface is half the ground reflected radiation on a horizontal downward surface. The ground reflected radiation on a horizontal upward surface equals zero.

What happens with the solar irradiation on the external wall ?

The direct solar irradiation is reflected based on the angle of incidence (if defined in the wall type editor, cf. section F.5).

The diffuse and ground reflected solar irradiation is reflected based on the global diffuse reflection factor (which is calculated from the angular reflection factors, by averaging the angular reflection factors over all angles of incidence, randomly distributed over a sphere).

All this reflected radiation from the external wall back to the solar zone is further ignored.

For a transparent wall the transmitted radiation from the direct solar irradiation is projected along the solar beam direction inside the adjacent internal zone onto the first encountered wall.

The transmitted radiation from the diffuse and ground reflected irradiation is emitted from the internal side of the wall to the interior using ideal diffuse radiation (according to Lambert's cosine law). This means that this transmitted radiation is distributed to the other surfaces of the internal zone proportional to the view factors from the original wall to the other walls of the internal zone. All reflected radiation within an internal zone is also spread diffusely.

The transmitted and reflected radiation are recursively further distributed using diffuse emission until the remaining radiation is small enough ($< 0.01 \text{ W}$).

For a non transparent wall the total absorbed solar radiation is absorbed by the wall surface node.

For a transparent wall Edwards' embedding technique is used to distribute the absorbed solar radiation over the successive layers of this wall.

Finally all solar irradiation is translated into imposed powers on system nodes.

D.6. Dynamic calculation principles

For every new calculation time step the boundary conditions (climate data, solar loads, ventilation, internal gains due to occupants, equipment and lights) are updated and imposed to the right nodes. Then the controls (heating, cooling, extra ventilation, sunshades) are set or cleared based on the condition results applied on the calculation solution for the previous time step.

The equations of the updated system are set up based on the Cranck-Nicolson method applied for every node:

heat flows at current time step + heat flows at previous time step = 2 x heat capacity change.

The obtained linear system of equations is then solved.

The system solution runs faster if the wall heat transfer coefficients (hg1, hc1, hg2, hc2 in the Walls window) and zone ventilation flows (in the Zone Ventilaton window) are not modified compared to the previous time step. These parameters require new coefficients in the system matrix, while the other parameters (imposed temperatures and powers) only change the constant terms of the right-hand side of the system.

Finally the solution and system parameters for the current time step are saved in memory to be able to rewind to these solutions from other time steps (using the commands of the Output submenu, cf. section D.4).

A calculation including multiple time steps (*Calc > Next Interval*, *Calc > Run Calc*) can be interrupted at any time by pressing the <Esc>-key. The solution is shown for the last finalised time step.

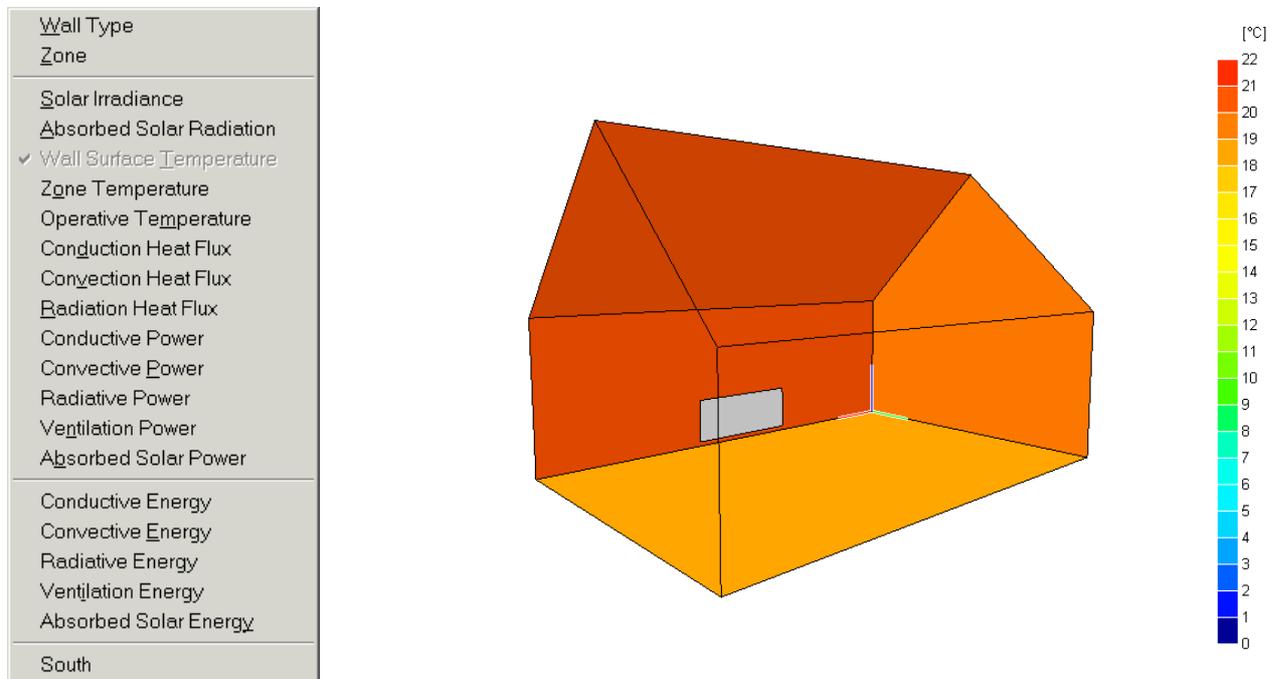
CHAPTER E OUTPUT

E.1. View commands

It is possible to load the results of each calculated time step using the commands of the Output submenu (cf. section D.4).

Different output quantities can be viewed in the Image window using the commands in the View submenu (cf. figure below left). The wall surfaces are coloured using these quantities (e.g. as in figure below right). The colour scale can be modified with the commands *Settings > Temperature Range...*, *Settings > Flux Range...*, *Settings > Power Range...*, *Settings > Energy Range...* or *Settings > Ventilation Flow Range...*

In select mode (*Image > Select* or shortcut key F1) the quantity value on the wall surface under the mouse point is displayed in the program status bar (at the bottom), when the mouse is moved.

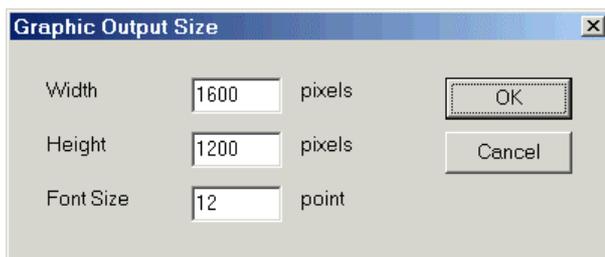


The different view options are:

- *View > Wall Type*: wall type colours as defined in Wall Types window (cf. section B.5).
- *View > Zone*: zone colours as defined in Zones window (cf. section B.6).
- *View > Solar Irradiance*: sum of direct and diffuse (including ground reflected) incoming solar radiation (in W/m^2) on external wall surfaces touching the solar zone.
- *View > Absorbed Solar Radiation* (in W/m^2) at wall surfaces.
- *View > Wall Surface Temperature* (in $^{\circ}\text{C}$).
- *View > Zone Temperature*: air (or fluidum) temperature (in $^{\circ}\text{C}$) in zone convection node.
- *View > Operative Temperature*: mean value (in $^{\circ}\text{C}$) of air temperature and radiation temperature (area weighted average of all surrounding wall surface temperatures).
- *View > Conduction Heat Flux*: heat flux (in W/m^2) at the wall surface by conduction (positive when leaving the wall flowing into the adjacent zone), calculated from the node temperatures and thermal resistance of the sublayer touching this wall surface.

- *View > Convection Heat Flux*: heat flux (in W/m^2) leaving the wall surface by convection (if adjacent zone has separate radiation and convection) or by global surface heat transfer (if adjacent zone has no separate radiation and convection).
- *View > Radiation Heat Flux*: heat flux (in W/m^2) leaving the wall surface by radiation (if adjacent zone has separate radiation and convection).
- *View > Conductive Power*: heat power (in W) into adjacent zone by conduction from all walls touching this zone.
- *View > Convective Power*: heat power (in W) into adjacent zone by convection (or global surface heat transfer) from all walls touching this zone.
- *View > Radiative Power*: heat power (in W) into adjacent zone by radiation from all wall surfaces touching this zone.
- *View > Ventilation Power*: heat power (in W) into adjacent zone by ventilation.
- *View > Absorbed Solar Power*: heat power (in W) by solar absorption at all wall surfaces touching adjacent zone.
- *View > Conductive Energy*: total energy (in kWh) into adjacent zone by conduction from all walls touching this zone, during last time interval (as defined in Time window).
- *View > Convective Energy*: total energy (in kWh) into adjacent zone by convection (or global surface heat transfer) from all walls touching this zone, during last time interval (as defined in Time window).
- *View > Radiative Energy*: total energy (in kWh) into adjacent zone by radiation from all wall surfaces touching this zone, during last time interval (as defined in Time window).
- *View > Ventilation Energy*: total energy (in kWh) into adjacent zone by ventilation during last time interval (as defined in Time window).
- *View > Absorbed Solar Energy*: total energy (in kWh) received by solar absorption at all wall surfaces touching adjacent zone, during last time interval (as defined in Time window).
- *View > South*: south direction (cf. section B.11).

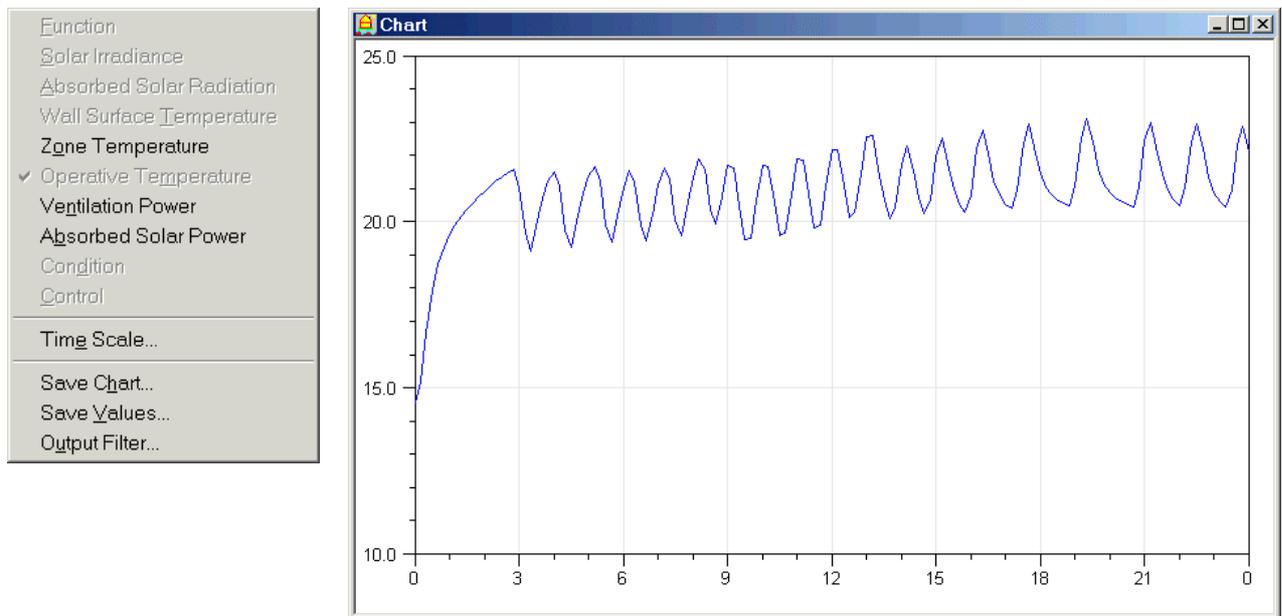
The image in the Image window can be saved in a PNG file using the command *Image > Save Image...*. The image in this file also contains a scale legend at the right side (cf. figure above right). The picture resolution (width and height in pixels) and font size of legend characters can be modified with the command *Settings > Graphic Output Size...* (cf. figure below).



E.2. Chart window

A chart shows an output quantity (e.g. temperature, flux, power) as a function of time in the Chart window.

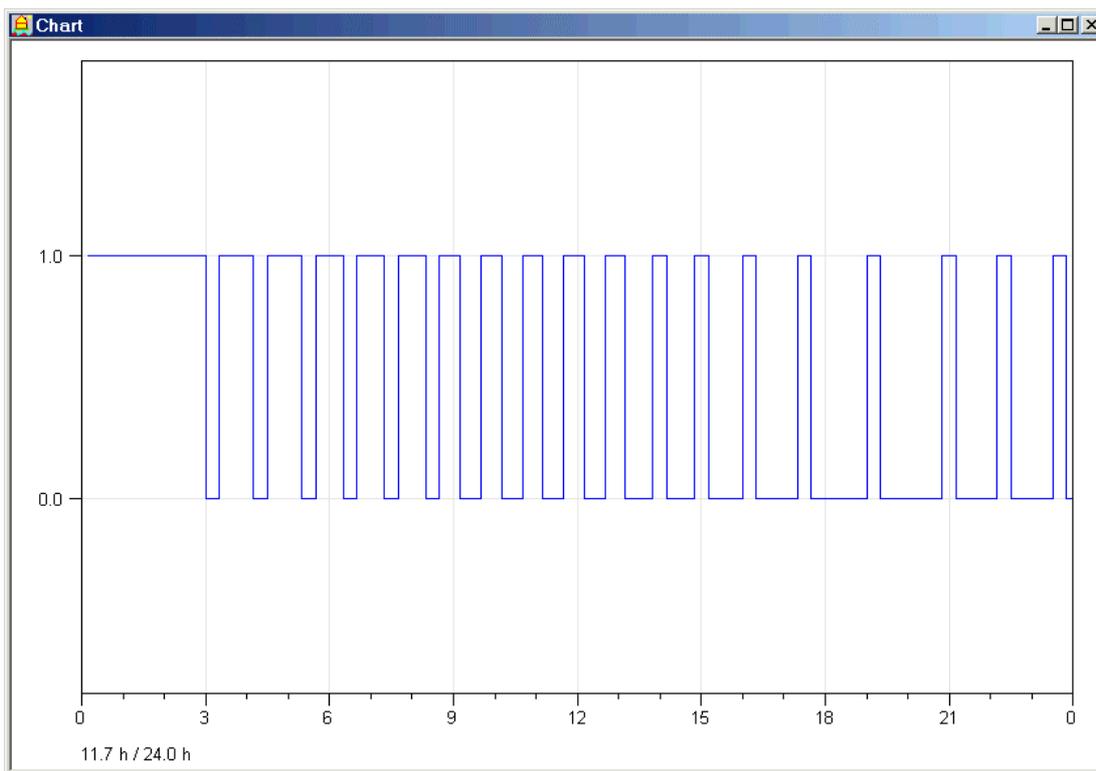
A chart (e.g. figure below right) is activated from the Chart submenu (cf. figure below left). The enabled commands depend on the context of the active window and cell.



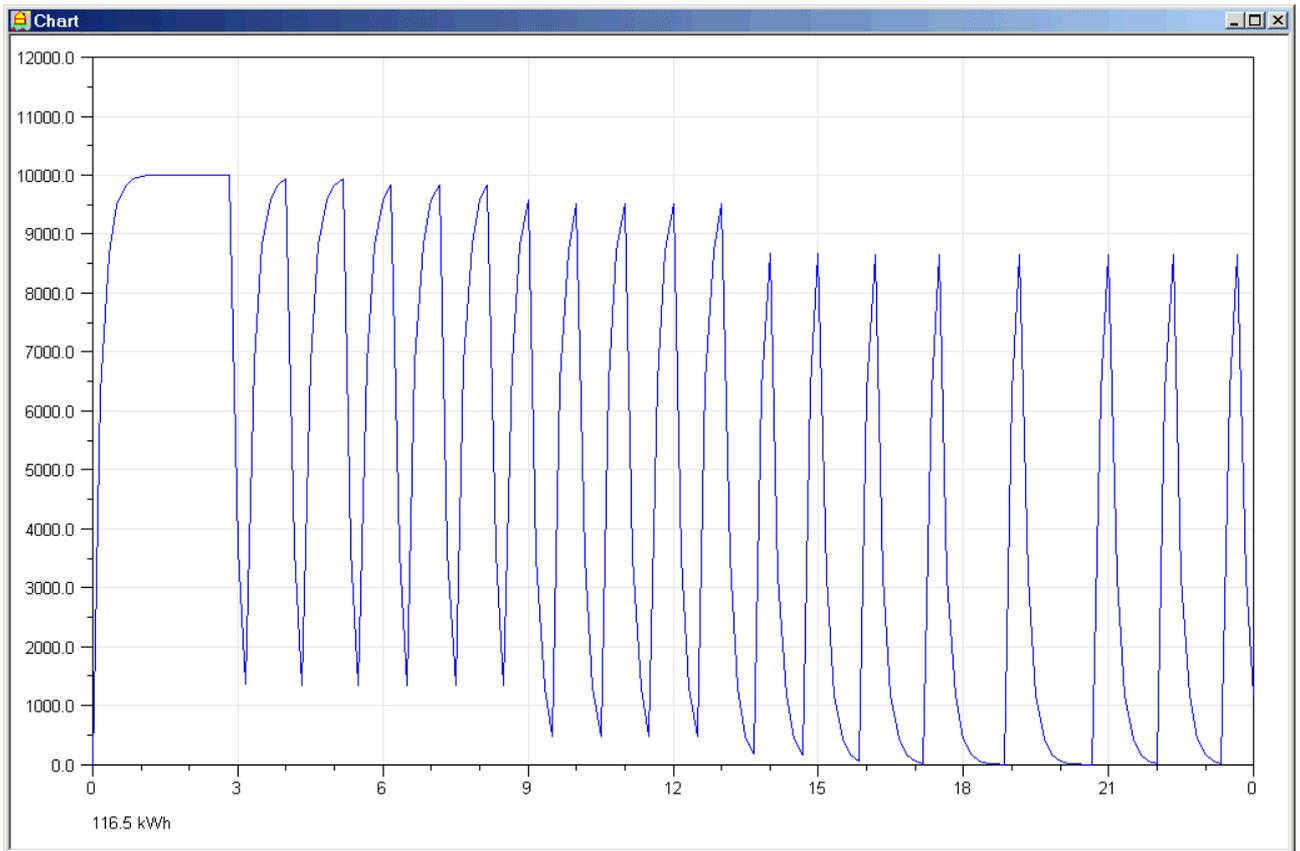
The possible commands creating a chart, are:

- *Chart > Function* (only enabled from the Functions window): shows the current function (determined by the position of the input cell in the Functions window).
- *Chart > Solar Irradiance* (only enabled from the Walls window): shows the solar irradiance (in W/m^2) on the current wall surface (determined by the position of the input cell in the Walls window, i.e. wall side 1 for column “From Zone”, “hg1”, “hc1”, and wall side 2 for column “To Zone”, “hg2”, “hc2”).
- *Chart > Absorbed Solar Radiation* (only enabled from the Walls window): shows the absorbed solar radiation (in W/m^2) at the current wall surface (determined by the position of the input cell in the Walls window, i.e. wall side 1 for column “From Zone”, “hg1”, “hc1”, and wall side 2 for column “To Zone”, “hg2”, “hc2”).
For an opaque wall surface this absorbed solar radiation multiplied by the wall surface is entirely released in the wall surface node.
For a transparent wall surface the absorbed power is released in the wall surface node and the different wall layer interface nodes according to the distribution calculated by Edwards’ embedding technique.
- *Chart > Wall Surface Temperature* (only enabled from the Walls window): shows the wall surface temperature (in $^{\circ}\text{C}$) at the current wall surface (determined by the position of the input cell in the Walls window, i.e. wall side 1 for column “From Zone”, “hg1”, “hc1”, and wall side 2 for column “To Zone”, “hg2”, “hc2”).
- *Chart > Zone Temperature* (only enabled from the Zones window): shows the zone air (or fluidum) temperature (in $^{\circ}\text{C}$) in the current zone (determined by the position of the input cell in the Zones window).
The zone temperature is either a boundary condition or the calculated temperature in the convection node (for a zone with separate radiation and convection).
- *Chart > Operative Temperature* (only enabled from the Zones window for zones with separate radiation and convection): shows the operative temperature (in $^{\circ}\text{C}$) in the current zone (determined by the position of the input cell in the Zones window).
The operative temperature is the mean value of the air temperature and the radiation temperature (area weighted average of all surrounding wall surface temperatures).
- *Chart > Ventilation Power* (only enabled from the Zones window): shows the ventilation power (in W) into the current zone (determined by the position of the input cell in the Zones window).
At the bottom left of the chart appears the total ventilation energy (in kWh) during the given time range of the chart.

- *Chart > Absorbed Solar Power* (only enabled from the Zones window): shows the total absorbed solar power (in W) at the wall surfaces bordering the current zone (determined by the position of the input cell in the Zones window).
This total absorbed solar power is evaluated as the sum of the solar absorption powers at all wall surfaces touching this zone.
At the bottom left of the chart appears the total absorbed solar energy (in kWh) during the given time range of the chart.
- *Chart > Condition* (only enabled from the Conditions window): shows the condition results (0 = false, 1 = true) of the current condition (determined by the position of the input cell in the Conditions window).
At the bottom left of the chart appears the total time (in h) that the condition result is true compared to the total time range of the chart.



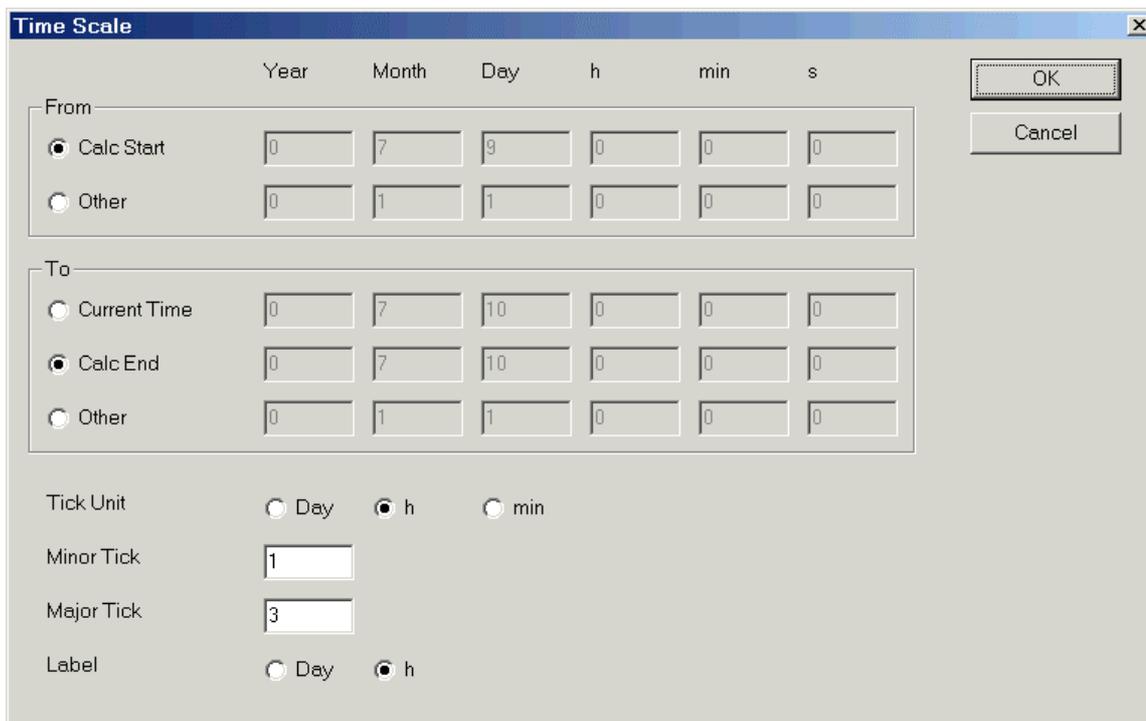
- *Chart > Control* (only enabled from the Controls window): shows either the control result (0 = off, 1 = on) or the control power (if the input cell is in the column “Pmax” and the control action is either heating or cooling; in W) for the current control (determined by the position of the input cell in the Controls window).
At the bottom left of the chart appears either the total time (in h) that the control is on compared to the total time range of the chart, or the total control energy (in kWh) during the given time range of the chart.



E.3. Chart time scale

The time scale defines the range of the horizontal axis of the chart and chart ticks on it. The command *Chart > Time Scale* opens a dialog box (cf. figure below) with the following parameters:

- From: calculation start (as defined in the Time window) or other user defined time.
- To: current time, calculation end (as defined in the Time window) or other user defined time.
- Tick unit: day in month, hour or minute.
- Minor tick: expressed in tick units (marks without labels).
- Major tick: expressed in tick units (multiple of minor tick and labelled).
- Label: day in month (1-31) or hour (0-23) printed beneath major tick marks.



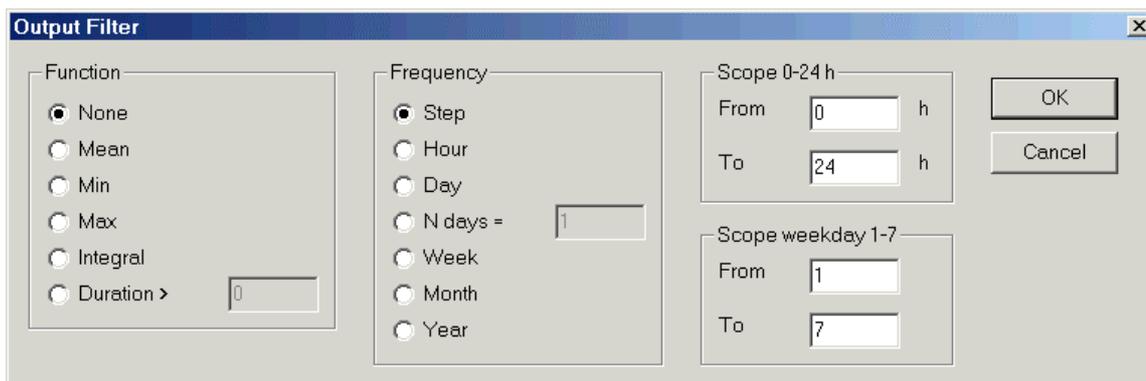
E.4. Save chart image, chart values and output filter

The command *Chart > Save Chart...* allows to save the chart (as in the Chart window) into a PNG image file.

The image resolution (width and height in pixels) and font size for labels are defined using the command *Settings > Graphic Output Size...* (cf. section B.12).

The command *Chart > Save Values...* allows to save the ordinate values of the chart into a text file (with extension .txt).

The output values are filtered using the parameters in the Output Filter dialog box (cf. figure below), opened with the command *Chart > Output Filter...*



The output filter parameters are:

- Statistical function applied to each set of values (in a fixed time interval, defined by the frequency):

None: no statistical function is used.

Mean: mean value.

Min: minimum value.

Max: maximum value.

Integral: sum of products of variable values and time step (time unit: h) for all time steps of

given time interval. E.g.: energy consumption as integral of heating power.

Duration >: time duration (in h) in which variable values are greater than a given constant value.

E.g.: temperature transgression duration.

– Output frequency:

Step: output per calculation time step.

Hour: output per hour.

Day: output per day.

N days: output per given number of days.

Week: output per 7 days.

Month: output per calendar month.

Year: output per 365 days.

– Time scope 0-24 h: only variable values within the given scope are included.

– Scope weekday (1 = Monday, 2 = Tuesday, ..., 7 = Sunday): only variable values within the given scope are included. January 1 (of year 0) is defined as a Monday.

CHAPTER F WALL TYPE EDITOR

F.1. Wall type composition

The wall type editor is a separate program (WallTypeEdit.exe) for the definition of the layer composition of wall types used in CAPSOL.

Each wall type consists of one or more layers.

The layers are ordered from side 1 toward side 2.

For external walls side 1 must correspond to the outside of the building, while side 2 corresponds to the inside.

CAPSOL must use this wall orientation in the definition of zones at both sides of each wall in the Walls window (cf. remark in section B.6).

External Wall.cwt																	
side1 => side2																	
No.	Name	Type	Pat	d [m]	λ [W/mK]	R [m ² K/W]	ρ [kg/m ³]	c [J/kgK]	Nu [-]	hrb [W/m ² K]	τ_s [-]	ϵ_{1ir} [-]	p_{1s} [-]	α_{1s} [-]	ϵ_{2ir} [-]	p_{2s} [-]	α_{2s} [-]
1	brickwork	NORMAL	■	0.09	1.000	0.090	1800	850	-	-	0	0.90	0.40	0.60	0.90	0.00	1.00
2	cavity	GAS	■	0.04	0.025	0.173	1.2	1000	2.5	5.15	-	-	-	-	-	-	-
3	ps extruded	NORMAL	■	0.06	0.035	1.714	30	1470	-	-	0	0.90	0.00	1.00	0.00	0.00	1.00
4	brickwork	NORMAL	■	0.14	0.500	0.280	1200	850	-	-	0	0.00	0.00	1.00	0.00	0.00	1.00
5	gypsum plaster	NORMAL	■	0.015	0.500	0.030	1300	840	-	-	0	0.00	0.00	1.00	0.90	0.50	0.50

dtot=0.345 m, Rtot=2.287 m²K/W with [h1=25.0 W/m²K, h2=7.7 W/m²K] U=0.41 W/m²K, g=0.00

There are two types of layers:

- Normal layers, used for solid materials.
- Gas layers, used for cavities.

A gas layer must always be enclosed between two normal layers (because the radiative resistance of the gas layer is dependent on the infrared emissivities of both adjacent material layer surfaces).

A new normal layer can be inserted using *Edit Layer > Insert Before (NORMAL)* or *Edit Layer > Insert After (NORMAL)*.

A new gas layer is inserted together with a normal layer using *Edit Layer > Insert Before (GAS+NORMAL)* or *Edit Layer > Insert After (GAS+NORMAL)*.

F.2. Properties of a normal layer

- Name.
- Type = NORMAL.
- Dot pattern (not used in CAPSOL v5.0w).
- d [m]: layer thickness
- λ [W/(m.K)]: thermal conductivity.
- R [m².K/W]: thermal resistance (R = d/ λ).
- ρ [kg/m³]: density.
- c [J/(kg.K)]: specific heat.
- τ_s : solar transmission factor.
- ϵ_{1ir} : infrared emission factor of exterior layer surface (at side 1).

- ρ_{1s} : solar reflection factor of exterior layer surface (at side 1).
The solar reflection factor ρ_{1s} of the first layer, adjacent to the exterior environment, can be defined in function of the angle of incidence (cf. section F.5).
- α_{1s} : solar absorption factor of exterior layer surface (at side 1).
- ε_{2ir} : infrared emission factor of interior layer surface (at side 2).
- ρ_{2s} : solar reflection factor of interior layer surface (at side 2).
- α_{2s} : solar absorption factor of interior layer surface (at side 2).

F.3. Properties of a gas layer

- Name.
- Type = GAS.
- Dot pattern (not used in CAPSOL v5.0w).
- d [m]: layer thickness
- λ [W/(m.K)]: thermal conductivity of the gas.
- ρ [kg/m³]: density of the gas.
- c [J/(kg.K)]: specific heat of the gas.
- Nu: Nusselt number of the gas layer.
If Nu = 1, then there is no convection and only conductive heat transfer.

The convective resistance of the gas layer is: $R_c = \frac{d}{\lambda \times Nu}$.

- h_{rb} [W/(m².K)]: black radiation heat transfer coefficient.
 $h_{rb} = \sigma \times (T_i^2 + T_j^2) \times (T_i + T_j)$
with $\sigma = 5.67 * 10^{-8}$ W/(m².K⁴) (Stefan-Boltzmann constant),
and T_i, T_j = absolute temperatures of adjacent material layer surfaces (unit: K).

The radiative resistance of the gas layer is: $R_r = \frac{\frac{1}{\varepsilon_1} + \frac{1}{\varepsilon_2} - 1}{h_{rb}}$

with $\varepsilon_1, \varepsilon_2$ = infrared emission factors of adjacent material layer surfaces.

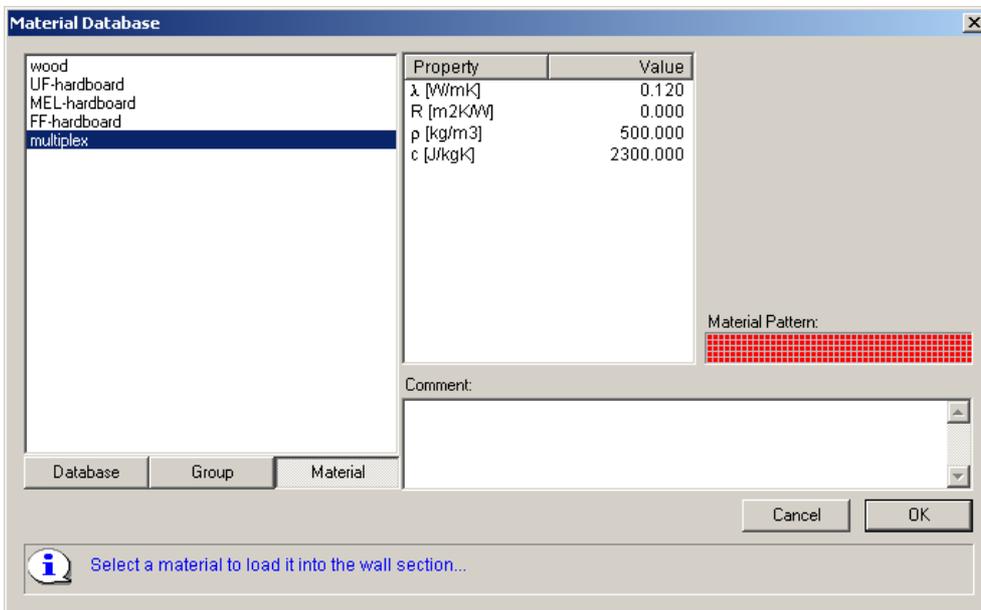
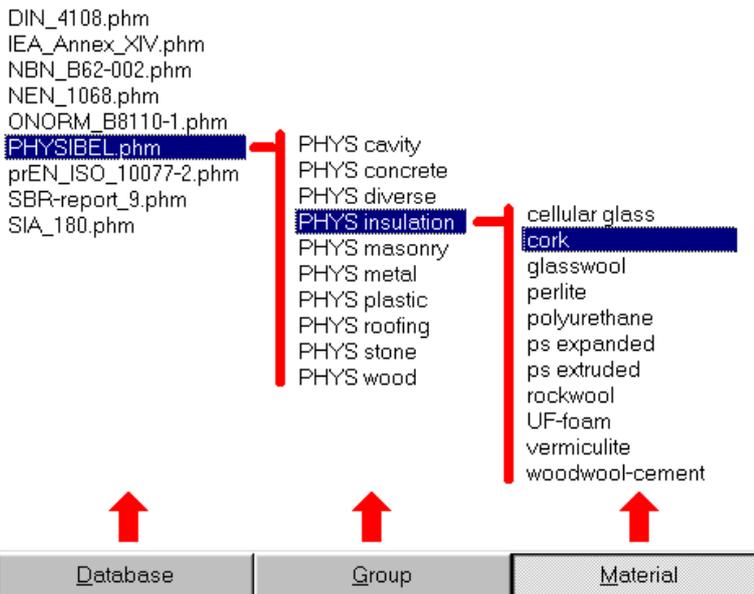
The total thermal resistance (in the column R, not editable) of the gas layer is: $R = \frac{1}{\frac{1}{R_c} + \frac{1}{R_r}}$.

F.4. Material database

Material properties can be selected from a material database using the command *Edit Layer > Load Material*.

The Material Database dialog box allows to choose a material database (e.g. based on a national standard), then a group of materials, and finally a material. The properties of the selected material are displayed and copied into the current layer when OK is pressed.

The available material databases are stored in text files with extension .phm in the data folder ..\Physibel\Materials. The files can be edited using the program MatEdit.exe in the same folder.



F.5. Angular dependent solar reflection factor

angle [°]	p [%]	refl [-]
0	0	0.27
15	0	0.27
30	0	0.27
45	1	0.28
60	14	0.37
75	46	0.61
90	100	1.00

$refl = p_{1s} + (1 - p_{1s}) \times \frac{p}{100}$
 (angular reflection factor of the exterior wall surface)

Cancel OK

For external walls (e.g. glazings) between the solar zone and an internal zone the solar reflection at the external side can be defined in function of the angle of incidence.

The solar reflection factor ρ_{1s} of the exterior layer surface as defined in the first layer (cf. section F.2) is considered as reference value, valid at normal incidence (angle of incidence = 0°).

The angular dependent solar reflection is defined in the dialog box opened with the command *Edit Layer > Edit Angular Reflection* using percentages p per angle (in steps of 15°):

$$\rho_{\theta} = \rho_{1s} + (1 - \rho_{1s}) \times \frac{p}{100}$$

with ρ_{θ} = solar reflection factor for angle of incidence θ ,

and ρ_{1s} = solar reflection factor of exterior layer surface of first layer.

The reflection factors of intervening angles are calculated by linear interpolation.

F.6. U-value and g-value calculation

The wall type editor calculates automatically the thermal transmittance (U-value) and total solar energy transmittance or solar factor (g-value). The calculation is according to the European standards EN 673 and EN 410.

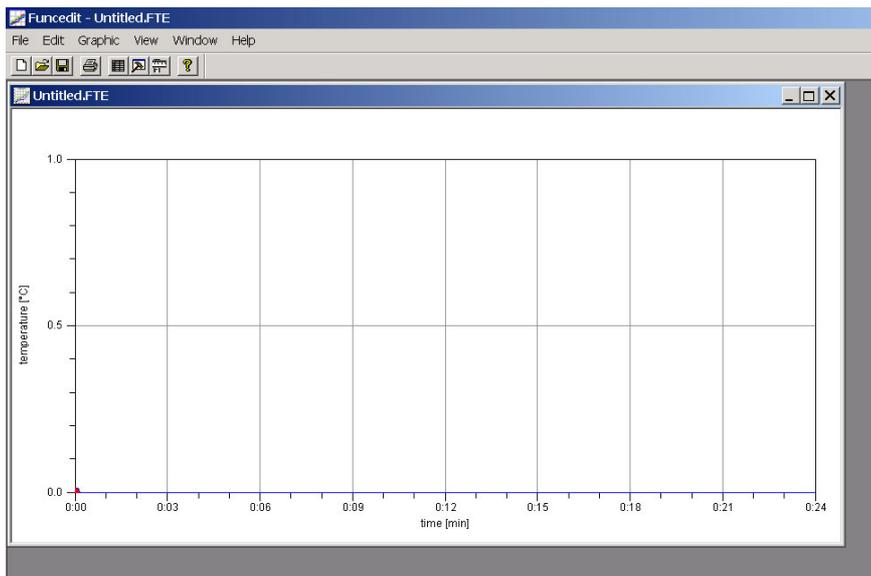
$\Sigma d=0.310 \text{ m}$, $\Sigma R=1.816 \text{ m}^2\text{K/W}$ with $h_1=25.0 \text{ W/m}^2\text{K}$, $h_2=7.7 \text{ W/m}^2\text{K}$ → $U=0.50 \text{ W/m}^2\text{K}$, $g=0.00$

CHAPTER G PROGRAM FUNCEDIT

G.1. Introduction

The function editor FUNCEDIT is a separate program (Funcedit.exe) to edit and visualise function files for use in CAPSOL (and the other non-steady state Physibel programs VOLTRA and BISTRA), 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 is opened with the command *File > Open....* The function type can be chosen in the Open dialog box.

G.2. Function types

The following function types are used in CAPSOL:

	unit	extension	use in CAPSOL
temperature	[°C]	.fte	boundary condition temperature
horizontal global solar radiation	[W/m ²]	.fsg	boundary condition in solar zone
horizontal diffuse solar radiation	[W/m ²]	.fsd	boundary condition in solar zone
infrared radiation	[W/m ²]	.fir	boundary condition heat flux
power	[W]	.ffh	boundary condition power
ventilation rate	[/h]	.fvr	ventilation volume flow rate [m ³ /h]

Remark

The ventilation rate in FUNCEDIT is displayed with unit /h, but is used in CAPSOL with unit m³/h.

G.3. Function parameters

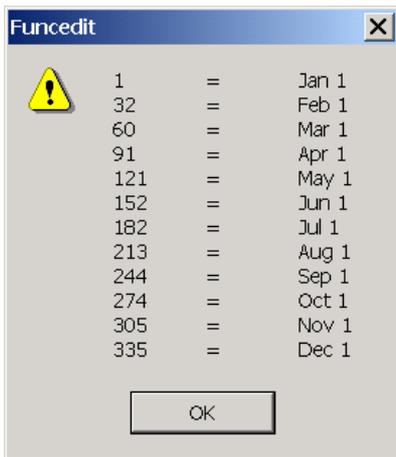
General header information of a function file is edited via the command *Edit > Parameters*.

The dialog box 'Function parameters' contains the following fields and options:

- Function type:** temperature [°C]
- Comment:** Climatic data Ukkel (Belgium)
- Previous function:** the same
- Next function:** the same
- Interpolation:** linear, step
- Time step:** 0000:01:00:00 (dddd:hh:mm:ss)
- Total steps:** 8760
- Number of decimals:** 1
- Number of columns:** 1
- Day number at function start:** 1, (1 Jan)
- Latitude [°N]:** 50.78 (-90° .. +90°, positive to the north)
- Longitude [°E]:** 4.37 (-180° .. +180°, positive to the east)
- Time zone [h]:** 1 (-12 .. +12, positive to the east, Greenwich = 0h)
- Chart time unit:** days, hours, minutes
- Chart time format:** 1 Jan 12:00, 1 Jan, 12:00, number

A dialog box is opened with the following parameters:

- **Function type:** see section G.2.
- **Comment:** text description of the function.
- **Previous function** and **next function:** file name of 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.
- **Interpolation:** linear or step. Intermediate function values are either obtained by linear interpolation (linear function) or remain constant during the whole time step (step function).
- **Time step** [dddd:hh:mm:ss]: time interval between two successive function values in the function data window (cf. section G.4).
- **Total steps:** number of time steps in function definition (= number of function values - 1).
- **Number of decimals:** number of digits after the decimal point, for all function values in the function data window (cf. section G.4) and in the function file.
- **Number of columns:** used in the function data window (cf. section G.4) and in the function file.
- **Day number at function start** [1..365]. The “i” button gives information about the start days of each month.



- Latitude [°N], longitude [°E] and time zone [h]: geographical position of function climate station.
- 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.

G.4. Function data

The function values every time step can be edited in the function data window, opened with the command *Edit > Data*. The table format is set by the function parameters (cf. section G.3).

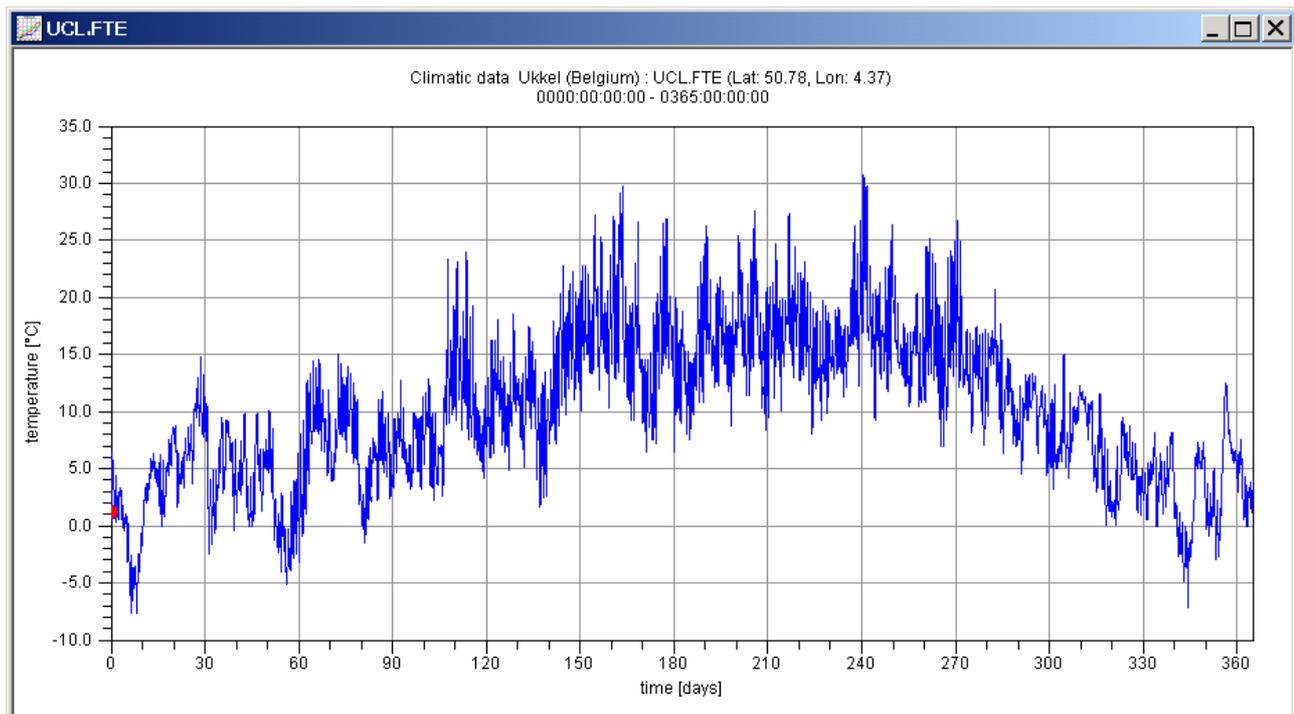
In the left (grey) column the time corresponding to the first value in the row is given.

A new value can be inserted using the command *Edit > Insert After* or the <Insert>-key. The “total steps” parameter in the function parameters dialog box is incremented accordingly.

A value can be deleted using the command *Edit > Delete Value* or the <Delete>-key.

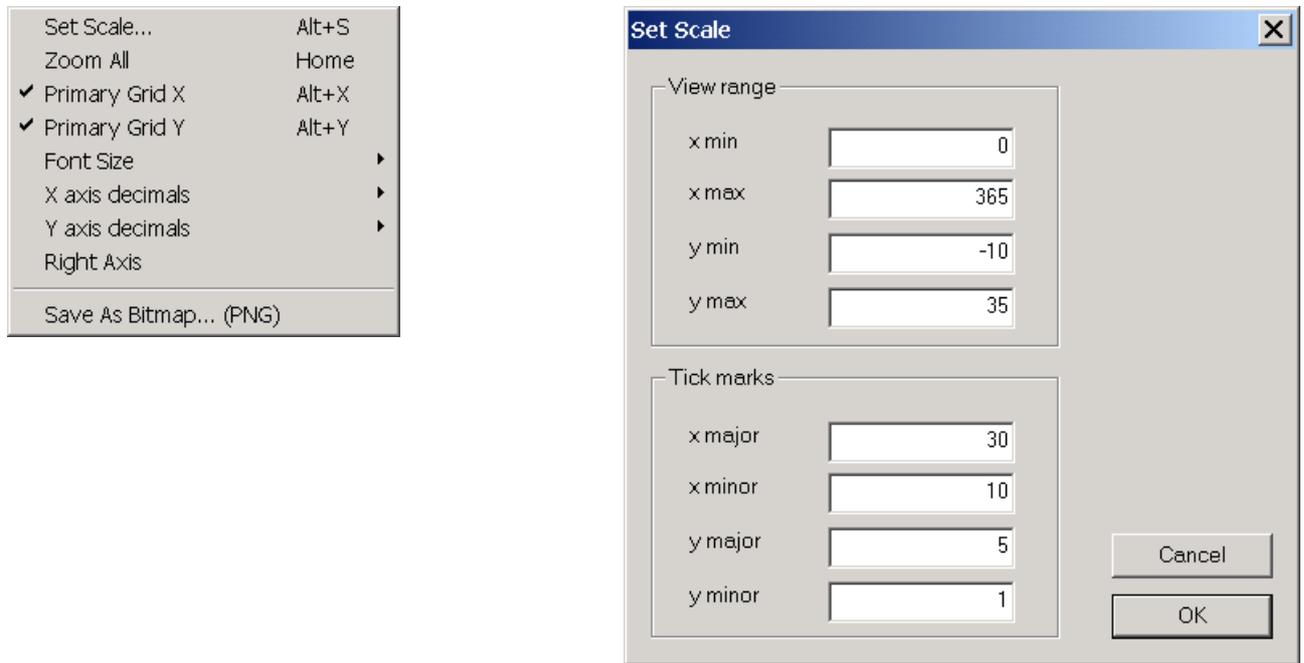
Individual table cells can be copied and pasted with *Edit > Copy* (or <Ctrl+C>) and *Edit > Paste* (or <Ctrl+V>).

G.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 commands in the Graphic submenu allows to edit the graph.



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 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 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 with file name and size of the PNG file, which is saved in the same directory as where the function file is stored.

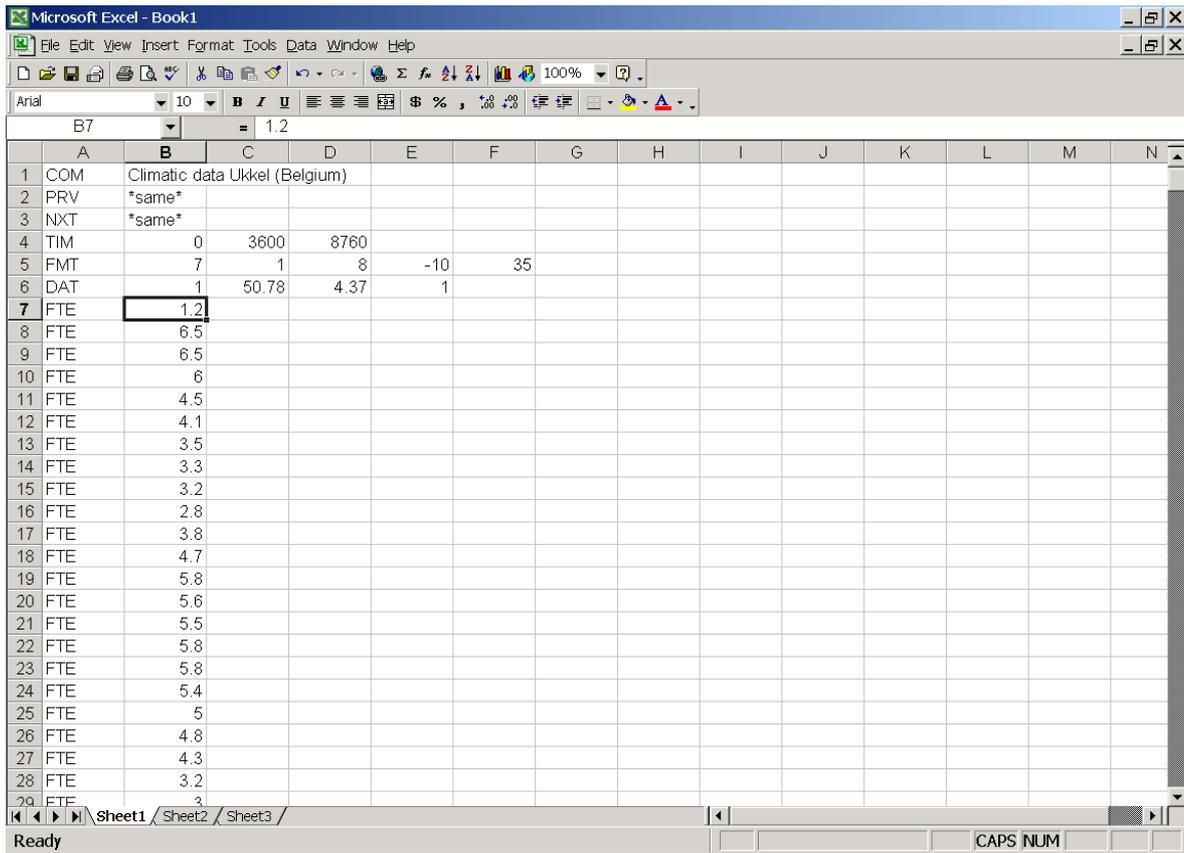
G.6. Using a spreadsheet program to create functions

A function file can also be created using Microsoft Excel.

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 data directory, with the extension corresponding to the function type (cf. section G.2).

If an existing function file, created with FUNCEDIT, has to be modified using a spreadsheet program, it is recommended to set the parameter “number of columns” in the Function Parameters

dialog box equal to 1. Then there is only 1 column with function values in the spreadsheet (as in the figure below).



row number	code column A	input data				
		column B	column C	column D	column E	column F
1	COM	comment				
2	PRV	name of previous function *				
3	NXT	name of 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 file extension may be omitted; use the name *same* to specify the same previous / next function.
 ** 3 letters as in file extension (cf. section G.2).