Summary of all help pages PCTempFlow computer program

Note: not internal links are functioning

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Purpose of the program

Short description

Short description of the PCTempFlow program:

Purpose of the program:

This program calculates the **time dependent** temperature distribution in a layered structure as a function of time.
The considered geometry is one-dimensional.
The program is primarily written in view of the calculation of fires, but is also suitable for use at much lower temperatures.

At the left side of the first layer at the right side of the last layer a prescribed heat source is present during a certain time.
There are THREE possibilities present for the input of the conditions:

1. Input of the air temperature [°C]
2. Input of the incoming radiation [kW/m^2]
3. Combination of point 1. and 2.

At point 1. next to air temperature the heat transition coefficient has to be given [W/m^2 °C]
For point 2. the first layer is radiating somewhat backwards as a consequence of the raise in temperature and therefore lowering the temperature somewhat (especially at higher surface temperatures).
For option 3. the amount of energy is put into the structure by convection as well as radiation.

For the input of air temperatures and radiation at both sides various more or less complex options are available.

In the various layers heat transport takes place by convection only.
It is possible, if water is present, to limit the temperatures to a maximum of 100 degrees Celsius.
In a possible cavity heat transport is only calculated by means of radiation.

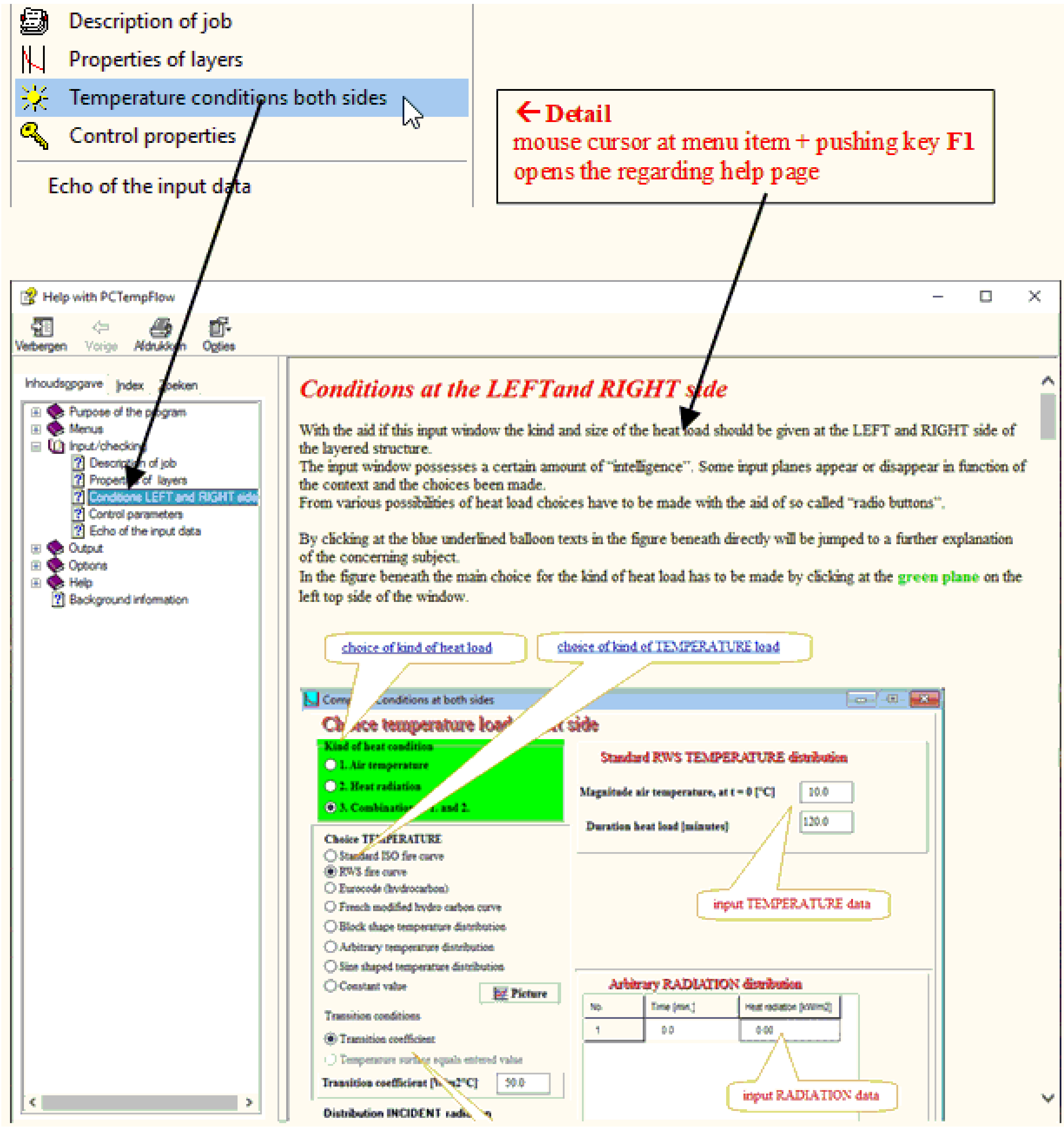
The output of the calculations results is possible in numerical as well as graphical form.

Limitation of the scope

For the material concrete any spalling in the event of a fire is not taken into account.
The process of concrete spalling in the event of a fire is a very complex mechanism for which no reliable calculation models are (yet) available.

Attention !!

Practically everywhere in the program help can be acquired by touching the function key **F1**.
Let for instance the mouse rest at a certain menu option and push at the same time de key F1; the context sensitive help will then appear (see also the example beneath).



At a number of windows also help can be acquired by pushing the special help button (pressing the **F1** key works also at these places).

Menus

New job

New job

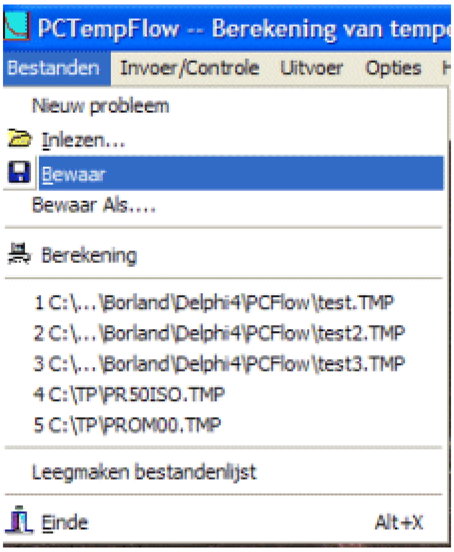
When the program starts the variables will be initialised automatically (an empty job).
The program can be "filled" via Load input and/or keyboard.
With the aid of this menu option the already present data will be deleted and overwritten with the new data.
Therefore be careful !!!
If the data is not saved to disk the problem variables are lost forever.

Open

Open a data file

With the aid of this menu option an already existing data file can be loaded.
The standard extension of the data files is "TMP".
It is recommended not to deviate from this standard extension, because otherwise the general view be lost.

The program keeps up also a list from most recent uses data files (MRU list); see the example beneath:



By clicking at one of the file names in de MRU list the data file will be loaded without any further dialog.
The list is allowed to occupy a maximum of 10 items.
New loaded files are appended at the top of the MRU list. When the number of items threatens to step across the number of 10 the item at the bottom will be deleted.
The MRU list can be made empty also.

Save

Save input data

With the aid of this menu the input data are saved to the hard disk or other medium.
The standard extension of the data files is "TMP".
It is recommended not to deviate from this standard extension, because otherwise the general view be lost.
At the moment a calculation should be performed this saving of files will be executed for reasons of security.

If the program already knows a name for the problem a name is not asked; the file will be saved directly.

An existing data file with the same name will be overwritten.

See further also: Save input As

Save As..,.

Save As ....

With the aid of this menu the input data of a problem can be saved to the hard disk or a diskette.
At the moment of saving the name of the problem is asked explicitly
The standard extension of the data files is “TMP”.
It is recommended not to deviate from this standard extension, because otherwise the general view be lost.

See further also: Save input

Calculation

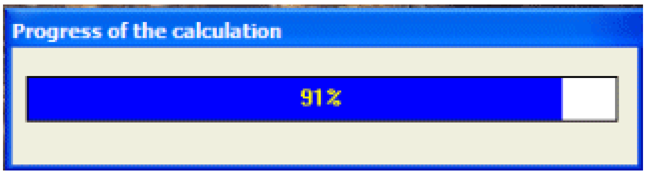
Start of the calculation

With the aid of this menu entry (or speed button) the calculation of the temperatures will be started.

When the calculation ends a window will be opened which gives the numerical output of the calculation.
The text is loaded from a file named by the user; but now with the extension “TMU”.

From the editor window the file can be printed via the button . With the aid of the button  paper margins etc. can be adjusted. These set ups will be preserved; also when the computer is shut down.
The different pages will be numbered at paper.
Further a fully-fledged editor is built in with various functions, which will not be described here (have to be self-explaining).

During the calculation a progress bar will show how far the calculation in progressed; see beneath:



Next to the numerical output the calculation results can be shown at a graphical way.

Exit

Exit

With the aid of this menu option the program can be closed (ended).

Already present job data gets lost; if needed use first Save input or Save input As.

Input/checking

Description of job

Description of the job

The use of this window is OPTIONAL

At this input window an arbitrary text can be typed which will be printed above the echo of the input data. Here for instance a description of the job can be input, where the backgrounds of the job could be given. Till a maximum of 10 lines of text are allowed.

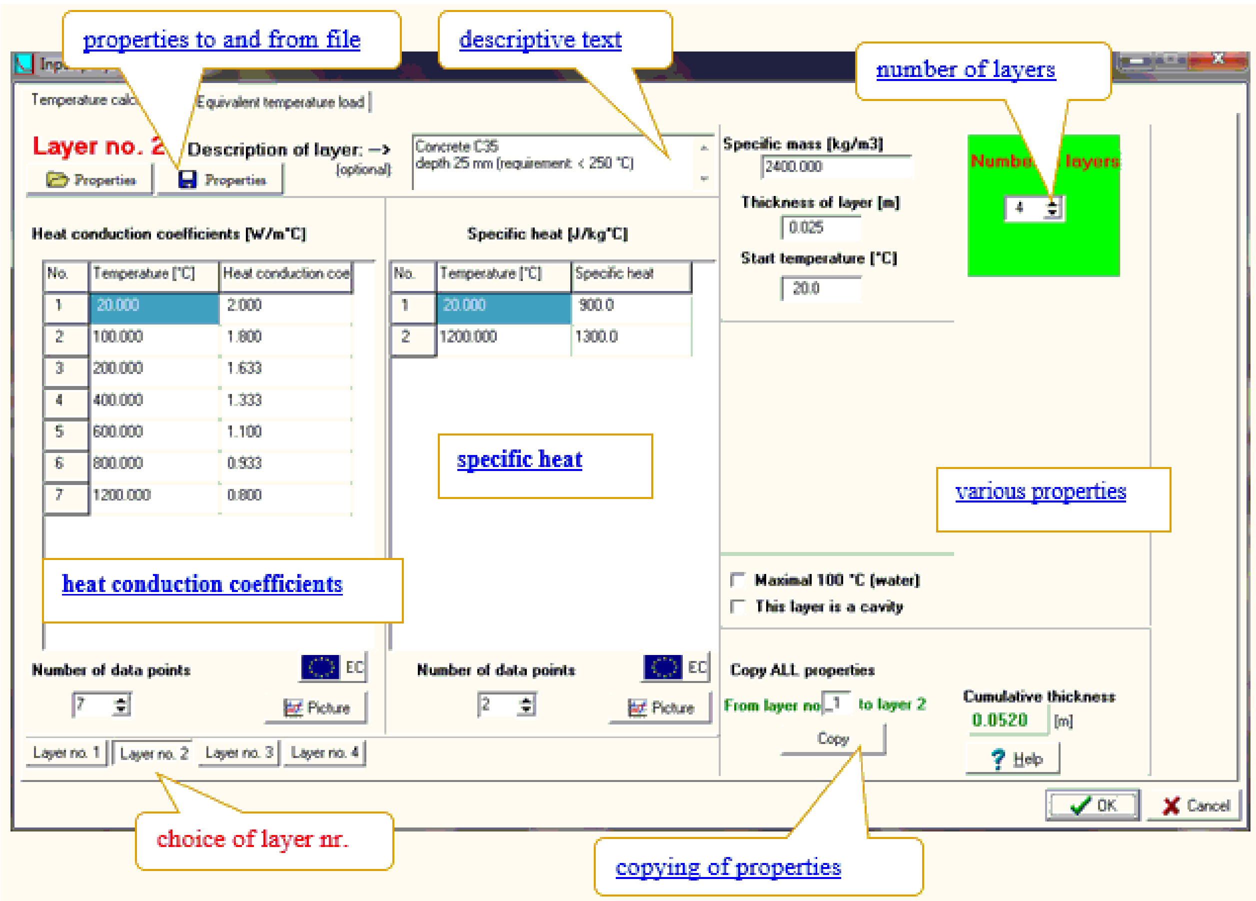
Properties of layers

Properties of the layers

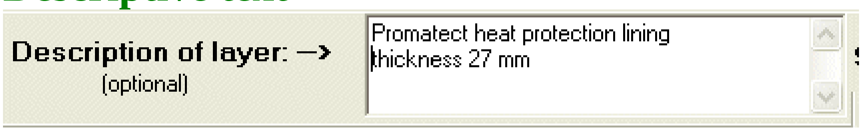
At the first tab sheet of this data entry window the various properties per layer for the calculation of the temperature distribution should be entered; at the second tab sheet the properties needed for the calculation of the equivalent temperature load should be entered.

First tab sheet

With the aid of this input window the various properties per layer have to be entered.
At the **green plane** at the top right side of the window the number of needed layers has to be adjusted.
These layers can also be "dummy" layers, because only at the transition of the various layers output as function of time can be acquired; see further also numerical output and graphical output.
At the manufacturing of such "dummy" layers a handy copying function is available; at which ALL properties of a entered layer number are copied into the active layer.
The input window possesses a certain measure of "intelligence". Some parts of the content of the window appears or disappears in relation to the context and the choices been made.
By clicking at the blue underlined balloon texts in the figure beneath directly will be jumped to a further explanation of the concerning subject.

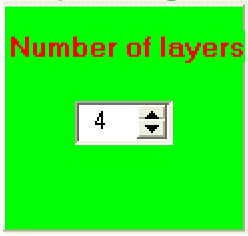


Descriptive text



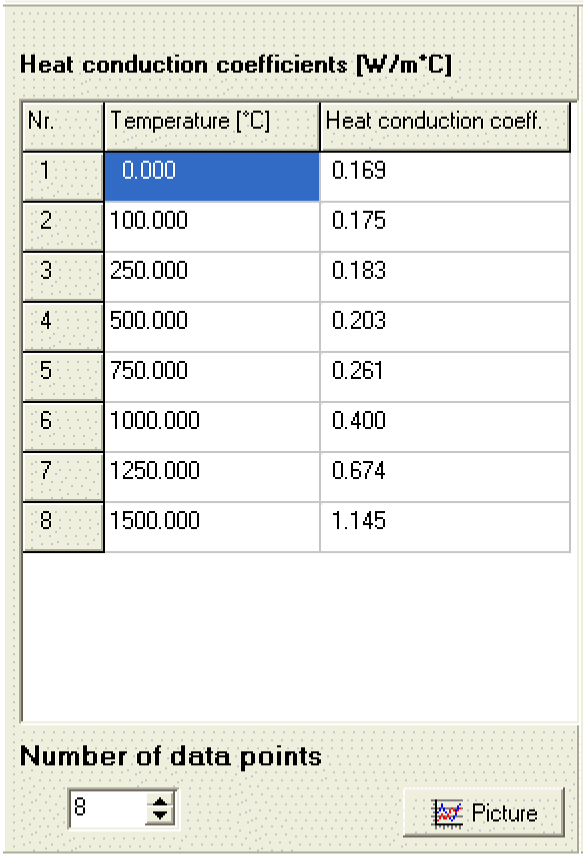
Per defined layer an arbitrary text can be entered, with which for instance background information can be given.
The text is allowed to have more than one line. This input is not compulsory.
Per layer this text will be shown at the echo of the input data and at the de numerical output.

Adjusting number of layers



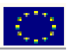
Here the number of layers wanted have to be entered (if necessary “dummy” layer).
If the number is changed the buttons at the bottom of the window appears or disappears.

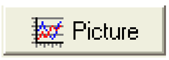
Heat conduction coefficients



Nr.	Temperature [°C]	Heat conduction coeff.
1	0.000	0.169
2	100.000	0.175
3	250.000	0.183
4	500.000	0.203
5	750.000	0.261
6	1000.000	0.400
7	1250.000	0.674
8	1500.000	1.145

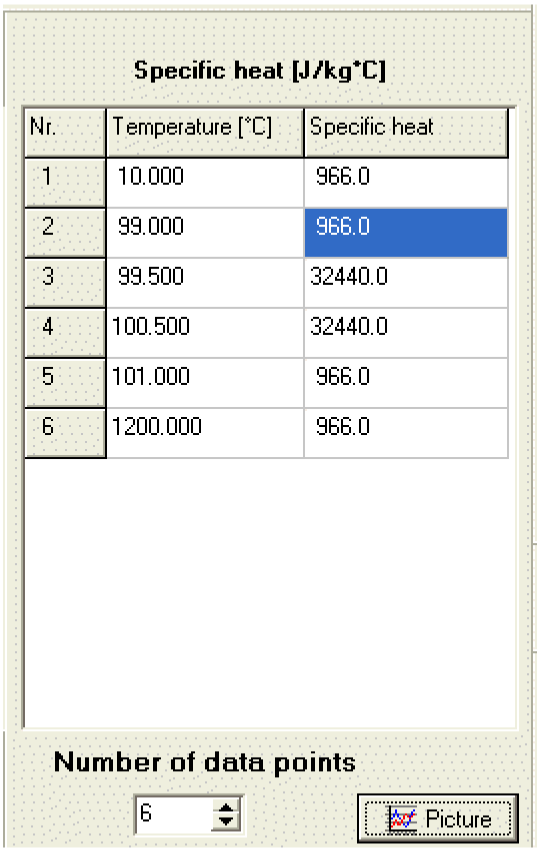
Here the temperature dependent heat conduction coefficients are entered by the user.
At the edit box at the bottom the user can change the number of input points.
The entered temperatures should have a rising distribution in time; this does not apply for the distribution of the heat conduction coefficients however.
Between the entered temperatures the program applies linear interpolation.
If only 1 input point is used the heat conduction coefficient is interpreted as a constant value by the program.
For temperatures which are higher than the highest entered temperature that value for the heat conduction coefficient is handled which belongs to the last entered input point.

With the aid of the button  the values according Eurocode EN 1992-1-2 are generated; see also data from Eurocode.

With the aid of the button 

for checking purposes a picture of the entered input data can be shown.

Specific heat values



Here the temperature dependent specific heat is entered by the user.
At the edit box at the bottom the user can change the number of input points.
The entered temperatures should have a rising distribution in time; this does not apply for the distribution of the specific heat however..
Between the entered temperatures the program applies linear interpolation.
If only 1 input point is used the specific heat conduction is interpreted as a constant value by the program.
For temperatures which are higher than the highest entered temperature that value for the specific heat conduction is handled which belongs to the last entered input point.

With the aid of the button the values according Eurocode EN 1992-1-2 are generated; see also data from Eurocode.

With the aid of the button **Picture** for checking purposes a picture of the entered input data can be shown.

Loading/saving material properties from/to file

With the aid of the button Properties the material properties in a layer can be **loaded** from a file.

With the aid of the button Properties the material properties in a layer can be **saved** to a file.
The file has the extension *.TempData
The installation program does place a number of files with material data at the directory *{app}\Mechanical Programs\TemperatureMaterialData*.
With *{app}* the part of the path name chosen by the user when installing the program.

The material files can be saved with the aid of the button Properties, but can be made, with the aid of a text editor, outside the program by the user too (ASCII characters).
The setup of the file has be **strictly** as follow:
line 1: Arbitrary text of the data file
lines 2 … **N**: Arbitrary text for the description of the material. With **N** is an arbitrary number of lines; N=2 in the example shown below
line N+1: The compulsory text “Specific mass”

line N+2: The value for the specific mass
line N+3: The compulsory text “Temperature   Heat conduction coefficients”
lines N+4....N+4+**H**: **H** lines with pairs of temperatures and heat conduction coefficients (separated by 1 or more spaces)
line N+4+H....N+4+H+1: The compulsory text “Temperature   Specific heat”
lines N+4+H+2....N+4+H+2+**S**: **S** lines with pairs of temperatures and specific heats (separated by 1 or more spaces)
line N+4+H+2+**S**+1: The compulsory text “E-modulus”
lines N+4+H+2+**S**+2....N+4+H+2+**S**+2+**M**: **M** lines with pairs of temperatures and values for the E-modulus (separated by 1 or more spaces)
line N+4+H+2+**S**+2+**M**+1: The compulsory text “Expansion coefficient”
lines N+4+H+2+**S**+2+**M**+2....N+4+H+2+**S**+2+**M**+2+**E**: **E** lines with pairs of temperatures and expansion coefficients (separated by 1 or more spaces)
line N+4+H+2+**S**+2+**M**+2+**E**+1: The compulsory text “Compression strength”
lines N+4+H+2+**S**+2+**M**+2+**E+2**….N+4+H+2+**S**+2+**M**+2+**E**+2+**C**: **C** lines with pairs of temperatures and compression strengths (separated by 1 or more spaces)

N, **H**, **S**, **M**, **E** and **C** are allowed to be arbitrary numbers (all ≥ 1).

```
PCTempFlow material properties for a certain material
Promatect H heat resistant lining
thickness 27 mm; with some moisture
Specific mass
 8.70000000000000E+0002
Temperature   Heat conduction coefficients
 2.00000000000000E+0001  1.69000000000000E-0001
 1.00000000000000E+0002  1.75000000000000E-0001
 2.50000000000000E+0002  1.83000000000000E-0001
 5.00000000000000E+0002  2.03000000000000E-0001
 7.50000000000000E+0002  2.61000000000000E-0001
 1.00000000000000E+0003  4.00000000000000E-0001
 1.25000000000000E+0003  6.74000000000000E-0001
 1.50000000000000E+0003  1.14500000000000E+0000
Temperature   Specific heat
 2.00000000000000E+0001  9.66000000000000E+0002
 9.90000000000000E+0001  9.66000000000000E+0002
 9.95000000000000E+0001  1.30000000000000E+0004
 1.00500000000000E+0002  1.30000000000000E+0004
 1.01000000000000E+0002  9.66000000000000E+0002
 1.50000000000000E+0003  9.66000000000000E+0002
E-modulus
 2.00000000000000E+0001  3.00000000000000E+0004
 1.00000000000000E+0002  1.87500000000000E+0004
 2.00000000000000E+0002  1.29500000000000E+0004
 3.00000000000000E+0002  9.11000000000000E+0003
 4.00000000000000E+0002  5.62500000000000E+0003
 5.00000000000000E+0002  3.00000000000000E+0003
 6.00000000000000E+0002  1.35000000000000E+0003
 7.00000000000000E+0002  9.00000000000000E+0002
 8.00000000000000E+0002  4.50000000000000E+0002
 9.00000000000000E+0002  2.40000000000000E+0002
 1.00000000000000E+0003  1.20000000000000E+0002
 1.10000000000000E+0003  3.00000000000000E+0001
Expansion coefficient
 2.00000000000000E+0001  1.00000000000000E+0000
 1.00000000000000E+0002  1.00000000000000E+0000
 2.00000000000000E+0002  1.05000000000000E+0000
 3.00000000000000E+0002  1.10000000000000E+0000
 4.00000000000000E+0002  1.25000000000000E+0000
```

5.00000000000000E+0002	1.40000000000000E+0000
6.00000000000000E+0002	1.67000000000000E+0000
7.00000000000000E+0002	2.00000000000000E+0000
8.00000000000000E+0002	1.00000000000000E-0001
9.00000000000000E+0002	1.00000000000000E-0001
1.00000000000000E+0003	1.00000000000000E-0001
1.10000000000000E+0003	1.00000000000000E-0001

Compression strength

2.00000000000000E+0001	3.50000000000000E+0001
1.00000000000000E+0002	3.50000000000000E+0001
2.00000000000000E+0002	3.32500000000000E+0001
3.00000000000000E+0002	2.97500000000000E+0001
4.00000000000000E+0002	2.62500000000000E+0001
5.00000000000000E+0002	2.10000000000000E+0001
6.00000000000000E+0002	1.57500000000000E+0001
7.00000000000000E+0002	1.05000000000000E+0001
8.00000000000000E+0002	5.25000000000000E+0000
9.00000000000000E+0002	1.75000000000000E+0000
1.00000000000000E+0003	1.40000000000000E+0000
1.10000000000000E+0003	3.50000000000000E-0001

Next to the input from a data file the data can be copied from one layer to another layer too; see further copying properties

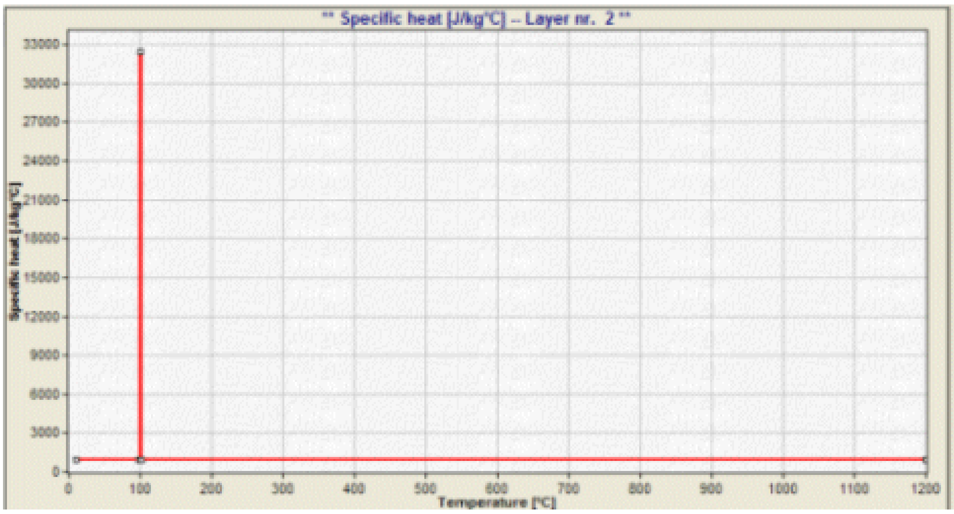
Special use of the specific heat

If a material possesses a certain amount of moisture at 100 °C all the moisture will evaporate before raising of the temperature above 100 °C.
During a certain amount of time locally a horizontal threshold as it were for the temperature development come into existence.
This evaporation effect can be simulated by taking the values of the specific heat around 100 °C much larger; see also the figures beneath:

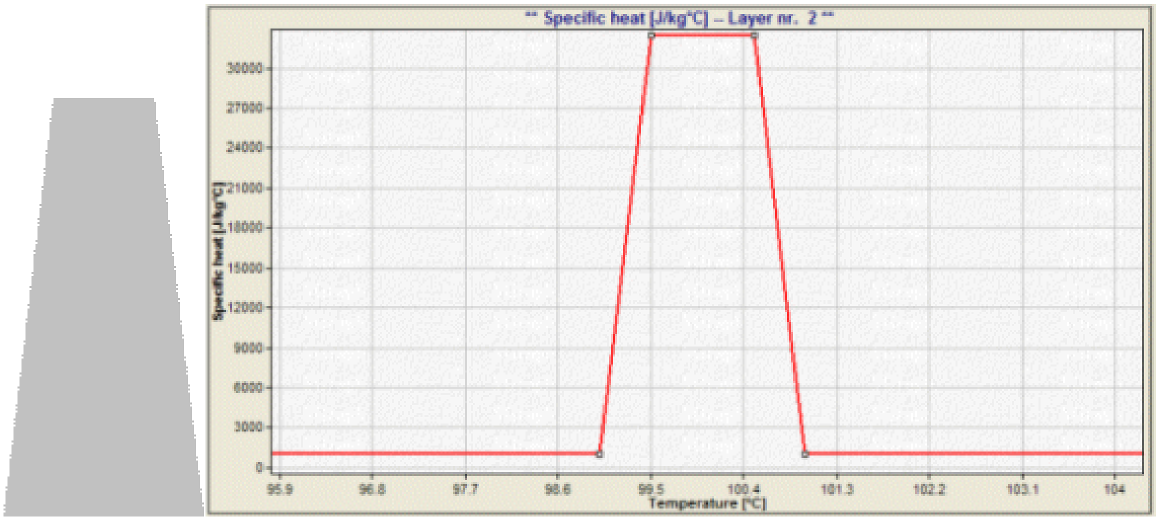
The area beneath the curve should be equal to the total evaporation heat of the amount of moisture present.
Starting from:

β = specific evaporation heat of water = 2260 10^3 [J/kg]
X = part of moisture in the material [kg/kg]=[-]
A = are beneath the hatched curve [J/kg]

A = **β.X**

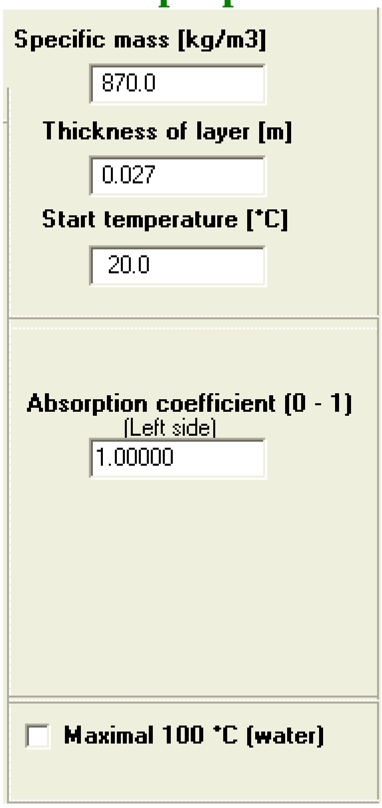


Example of the “nail” in the specific heat in order to simulate the evaporation

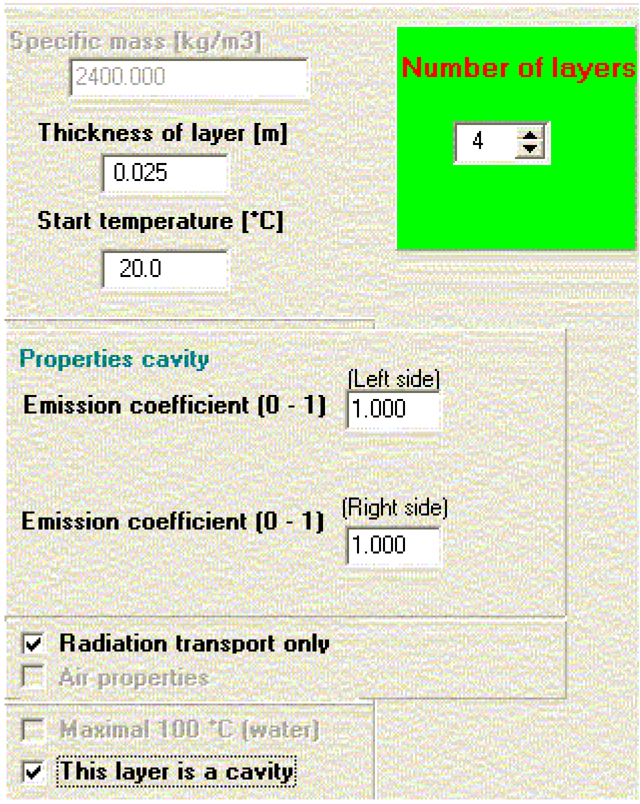


Magnification of the “nail”

Various properties



Standard input data



Input data if a cavity is present

Per layer **standard** a number of constants should be entered (see the left picture above):

- Specific mass
- Thickness of the layer
- Start temperature; at time t = 0
- Emission coefficient at the left side of the first layer; at the other layers no emission coefficient can be entered; unless the layer is a cavity

The emission coefficient at the left side of the structure is used for the first layer if also radiation load is present. For a value of “1” the material acts in relation to heat radiation as an ideal “black radiator”; for a value of “0” all radiation is reflected. For most of the building materials the value for the specific heat lies between 0.9 and 1.0.

Only metals can possess considerably lower values. Further the emission coefficient is in principle

temperature dependent; this aspect is neglected here however. The colour (e.g. white) says nothing about the value of the emission coefficient for long waved radiation. Unless special radiation shields are applied it is advised for reasons of simplicity to take the value of “1” for the emission coefficient.
For short waved radiation (e.g. light) other values applies; for that case the colour of the surface is of great interest.

For some values for ε see table below:

Surface Material	Emissivity Coefficient - ε -
Alloy 24ST Polished	0.09
Alumina, Flame sprayed	0.8
Aluminum Commercial sheet	0.09
Aluminum Foil	0.04
Aluminum Commercial Sheet	0.09
Aluminum Heavily Oxidized	0.2 - 0.31
Aluminum Highly Polished	0.039 - 0.057
Aluminum Anodized	0.77
Aluminum Rough	0.07
Aluminum paint	0.27 - 0.67
Antimony, polished	0.28 - 0.31
Asbestos board	0.96
Asbestos paper	0.93 - 0.945
Asphalt	0.93
Basalt	0.72
Beryllium	0.18
Beryllium, Anodized	0.9
Bismuth, bright	0.34
Black Body Matt	1.00
Black lacquer on iron	0.875
Black Parson Optical	0.95
Black Silicone Paint	0.93
Black Epoxy Paint	0.89
Black Enamel Paint	0.80
Brass Dull Plate	0.22
Brass Rolled Plate Natural Surface	0.06
Brass Polished	0.03
Brass Oxidized 600°C	0.6
Brick, red rough	0.93
Brick, fireclay	0.75
Cadmium	0.02
Carbon, not oxidized	0.81
Carbon filament	0.77
Carbon pressed filled surface	0.98
Cast Iron, newly turned	0.44
Cast Iron, turned and heated	0.60 - 0.70
Cement	0.54
Chromium polished	0.058
Clay	0.91
Coal	0.80
Concrete	0.85
Concrete, rough	0.94
Concrete tiles	0.63
Cotton cloth	0.77
Copper electroplated	0.03
Copper heated and covered with thick oxide layer	0.78
Copper Polished	0.023 - 0.052
Copper Nickel Alloy, polished	0.059

Glass smooth	0.92 - 0.94
Glass, pyrex	0.85 - 0.95
Gold not polished	0.47
Gold polished	0.025
Granite	0.45
Gravel	0.28
Gypsum	0.85
Ice smooth	0.966
Ice rough	0.985
Inconel X Oxidized	0.71
Iron polished	0.14 - 0.38
Iron, plate rusted red	0.61
Iron, dark gray surface	0.31
Iron, rough ingot	0.87 - 0.95
Lampblack paint	0.96
Lead pure unoxidized	0.057 - 0.075
Lead Oxidized	0.43
Limestone	0.90 - 0.93
Lime wash	0.91
Magnesia	0.72
Magnesite	0.38
Magnesium Oxide	0.20 - 0.55
Magnesium Polished	0.07 - 0.13
Marble White	0.95
Masonry Plastered	0.93
Mercury liquid	0.1
Mild Steel	0.20 - 0.32
Molybdenum polished	0.05 - 0.18
Mortar	0.87
Nickel, elctroplated	0.03
Nickel, polished	0.072
Nickel, oxidized	0.59 - 0.86
Nichrome wire, bright	0.65 - 0.79
Oak, planed	0.89
Oil paints, all colors	0.92 - 0.96
Paper offset	0.55
Plaster	0.98
Platinum, polished plate	0.054 - 0.104
Pine	0.84
Plaster board	0.91
Porcelain, glazed	0.92
Paint	0.96
Paper	0.93
Plaster, rough	0.91
Plastics	0.90 - 0.97
Polypropylene	0.97
Polytetrafluoroethylene (PTFE)	0.92
Porcelain glazed	0.93
Pyrex	0.92
PVC	0.91 - 0.93
Quartz glass	0.93
Roofing paper	0.91

Rubber, foam	0.90
Rubber, hard glossy plate	0.94
Rubber, natural hard	0.91
Rubber, natural oft	0.86
Salt	0.34
Sand	0.76
Sandstone	0.59
Sapphire	0.48
Sawdust	0.75
Silica	0.79
Silicon Carbide	0.83 - 0.96
Silver Polished	0.02 - 0.03
Soil	0.90 - 0.95
Steel Oxidized	0.79
Steel Polished	0.07
Stainless Steel, weathered	0.85
Stainless Steel, polished	0.075
Stainless Steel, type 301	0.54 - 0.63
Steel Galvanized Old	0.88
Steel Galvanized New	0.23
Thoria	0.28
Tile	0.97
Tin unoxidized	0.04
Titanium polished	0.19
Tungsten polished	0.04
Tungsten aged filament	0.032 - 0.35
Water	0.95 - 0.963
Wood Beech, planned	0.935
Wood Oak, planned	0.885
Wood, Pine	0.95
Wrought Iron	0.94
Zinc Tarnished	0.25
Zinc polished	0.045

If the air temperature or flame temperature is higher than the temperature at the surface, this additional radiation effect will cause the temperature at the surface to become somewhat higher (in the heating phase). Conversely, if the air temperature is lower than the temperature at the surface, this radiation effect will cause the temperature to become somewhat lower (in the cooling phase). At higher temperatures, this radiation effect increases considerably, according to Boltzmann's law ($\approx T^4{}_{,Kelvin}$).

- Checking of the box, at the bottom of the input window, for whether or not the maximum temperature should exceed the 100 °C limit; e.g. at the presence of an excess of water.

Cavity (see the right figure above)
With the exception of the first and last layer a layer in between can also be a cavity; make a choice by checking the concerning box.
For the case of a cavity at both the left and the right side of the layer an emission coefficient should be entered (see the right picture above).
The heat transfer over a cavity will by radiation only.
The cavities are not allowed to be situated right next to each other; the program does check this.

Copying of properties

With the aid of this option ALL properties of a certain layer can be copied to the active layer (e.g. from 1 to 4, or 3 to 2).
This option is especially handy in order to make at a quick way “dummy” layers; only the thickness needs to be adjusted if necessary.
“Dummy” layers have the purpose to fabricate virtual transitions planes in order to make output of the calculated temperatures at those places possible; see further also numerical output and graphical output.

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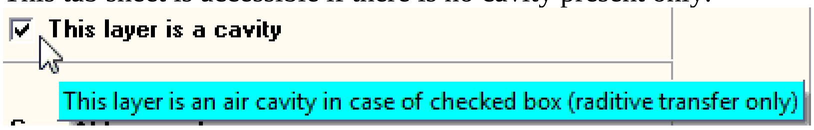
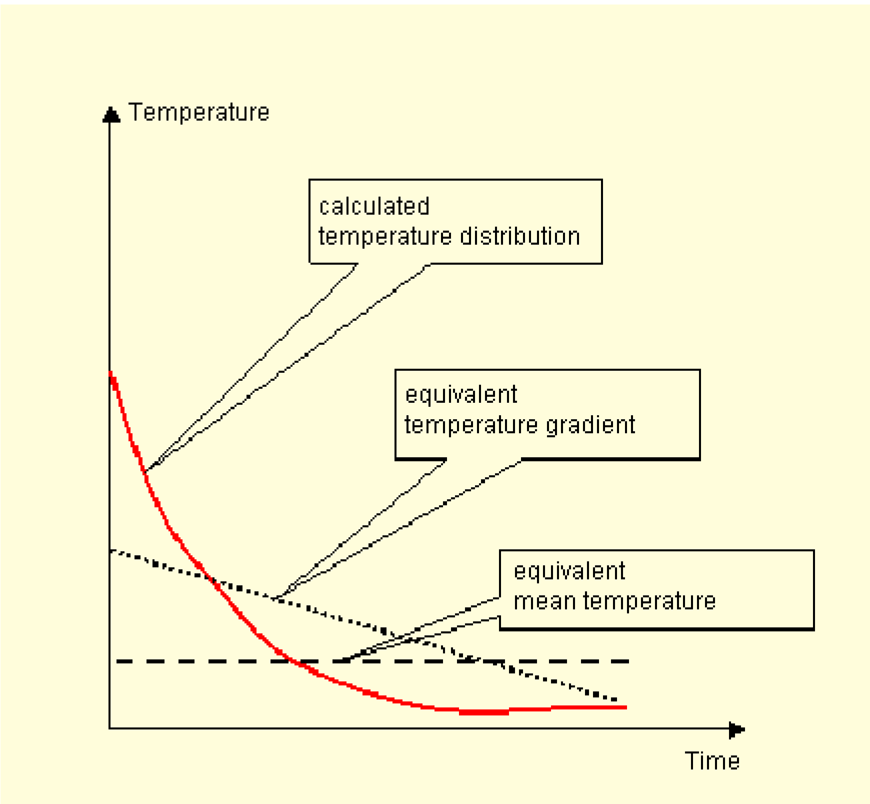
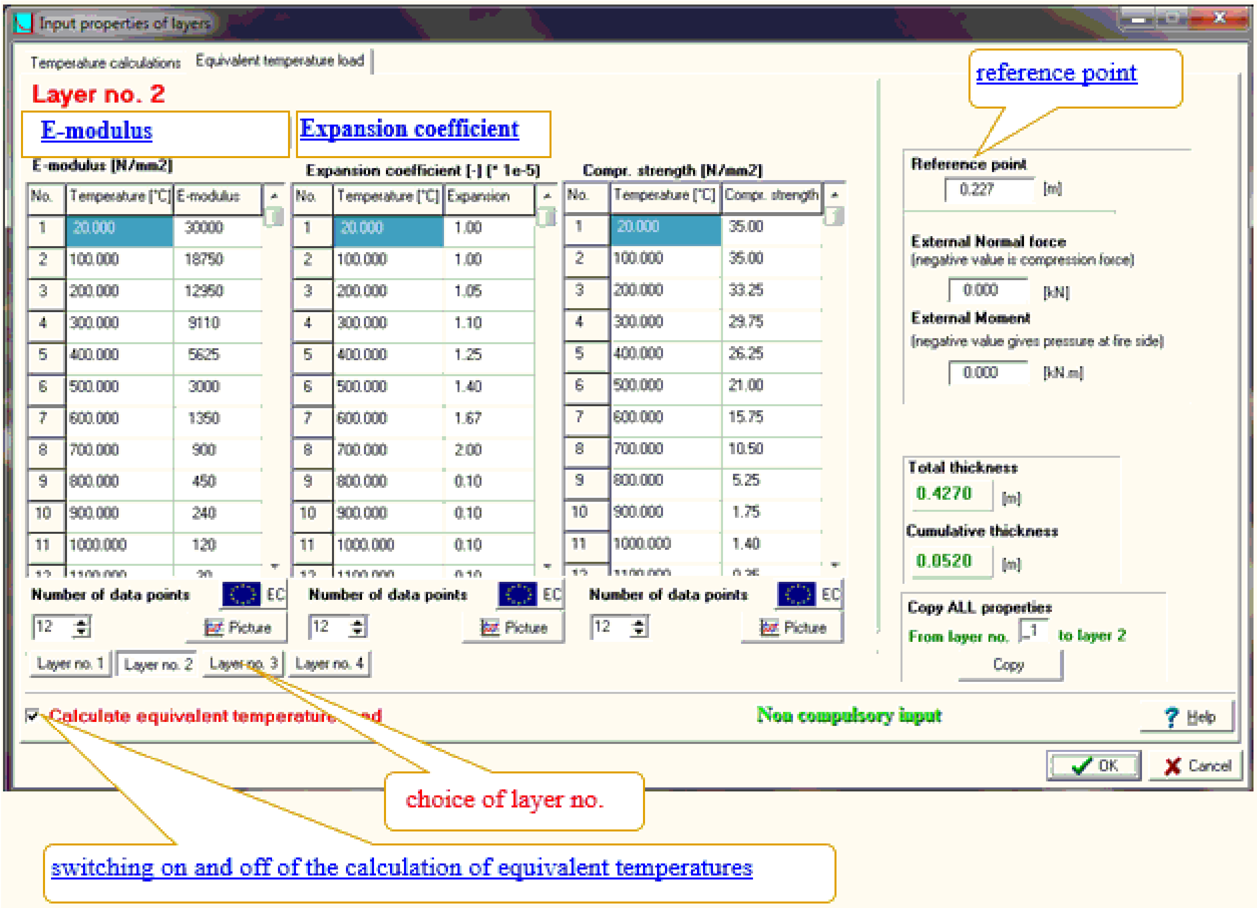
Second tab sheet

At this tab sheet the needed data for the calculation of the ***equivalent temperature load*** can be entered; the use of this tab sheet is **NON** compulsory.
This tab sheet is accessible if there is no cavity present only.



Using the ***equivalent*** mean temperature and gradient as input in a framework program (using the value for the E-modulus at 'normal' temperatures [20°C]) calculates the same force distribution in the frame as the true non-linear temperature distribution at a given time.
The program Framework does support the input and calculation of temperature beam loads for instance.
This should be calculated for the time-step with the maximal equivalent linear temperature distribution to find the maximal effect for the structure of course.





The input data below is needed in order to be able to calculate the stresses, with the aid of the linear equivalent temperature distribution and with **completely** restrained external deformations.

E-modulus

At the data grid the value for the E-modulus for each layer can be entered as function of the temperature.
In general the E-modulus decreases with larger temperatures; which results in relatively less influence on the acting forces if the temperatures are higher.
For the forces generated by the non linear temperature distribution acting in the section the value of the varying E-modulus will be taken into account.
The program takes, for the calculation of the equivalent linear temperature distribution (mean value and gradient), the first entered value (no. 1) for the E-modulus as starting point; see further also background information.

With the aid of the button the values according Eurocode EN 1992-1-2 (concrete) are generated; see also data from Eurocode.

Expansion coefficient

At the data grid the value for the expansion coefficient for each layer can be entered as function of the temperature.
The entered values will be multiplied by the program with a factor 10^{-5}!!
For the forces generated by the non linear temperature distribution acting in the section the value of the varying expansion coefficient will be taken into account.
The program takes, for the calculation of the equivalent linear temperature distribution (mean value and gradient), the first entered value (no. 1) for the expansion coefficient as starting point; see further also background information

With the aid of the button the values according Eurocode EN 1992-1-2 (concrete) are generated; see also data from Eurocode.

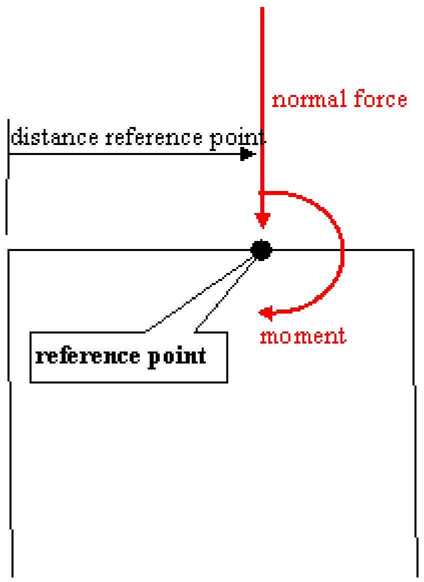
Compression strength

At the data grid the value for the maximum compression strength for each layer can be entered as function of the temperature.

With the aid of the button the values according Eurocode EN 1992-1-2 (concrete) are generated; see also data from Eurocode.

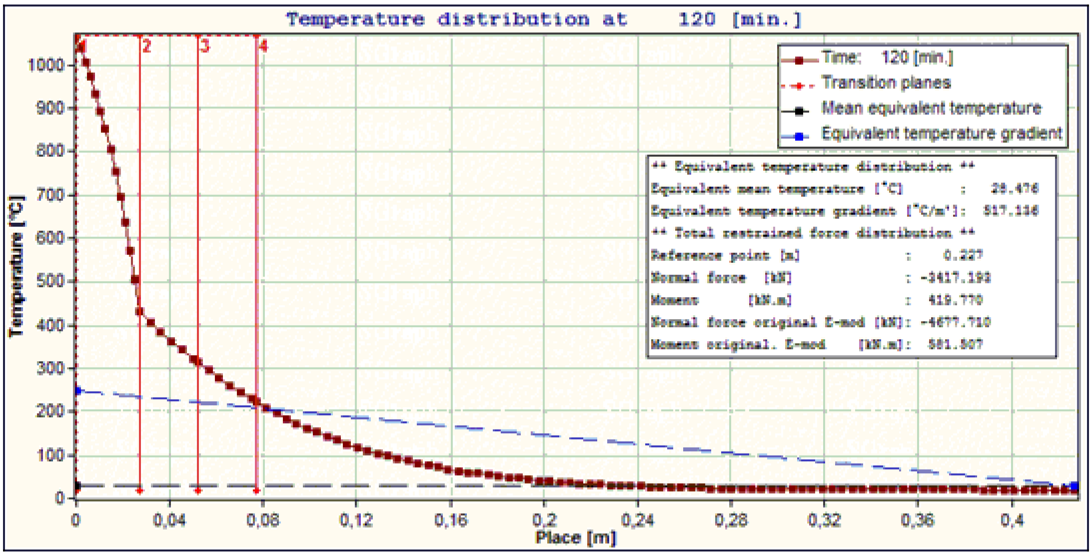
Reference point

By means of the reference point it's defined in relation to which point the moment causes by the temperature distribution is determined.
For this reference point every point in the section can be chosen; for instance half way the thickness of the section; see for illustration purposes the figure below:



Switching on and off of the calculation of equivalent temperatures and stresses

The equivalent temperature distribution (mean value and gradient) and stresses will be calculated if this box is checked only.
The equivalent temperature distribution and stresses will be shown both as numerical output and graphical output.
See the examples below:



Real and equivalent temperature distribution

```
** Equivalent temperature distribution **
Equivalent mean RISE in temperature [°C]: 20,661
Equivalent temperature gradient [°C/m'] : 295,162
** Total restrained force distribution **
Reference point [m]               : 0,227
Normal force  [kN]                : -2931,853
Moment        [kN.m]              : 380,472
Normal force original E-mod [kN]: -4013,531
Moment original. E-mod     [kN.m]: 531,198
```

Using the ***equivalent*** mean temperature and gradient as input in a framework program (using the value for the E-modulus at 'normal' temperatures [20°C]) calculates the same force distribution in the frame as the true non-linear temperature distribution at a given time .
The program Framework does support the input and calculation of temperature beam loads for instance.
This should be calculated for the time-step with the maximal equivalent linear temperature distribution to find the maximal effect for the structure of course.

Prevented stresses

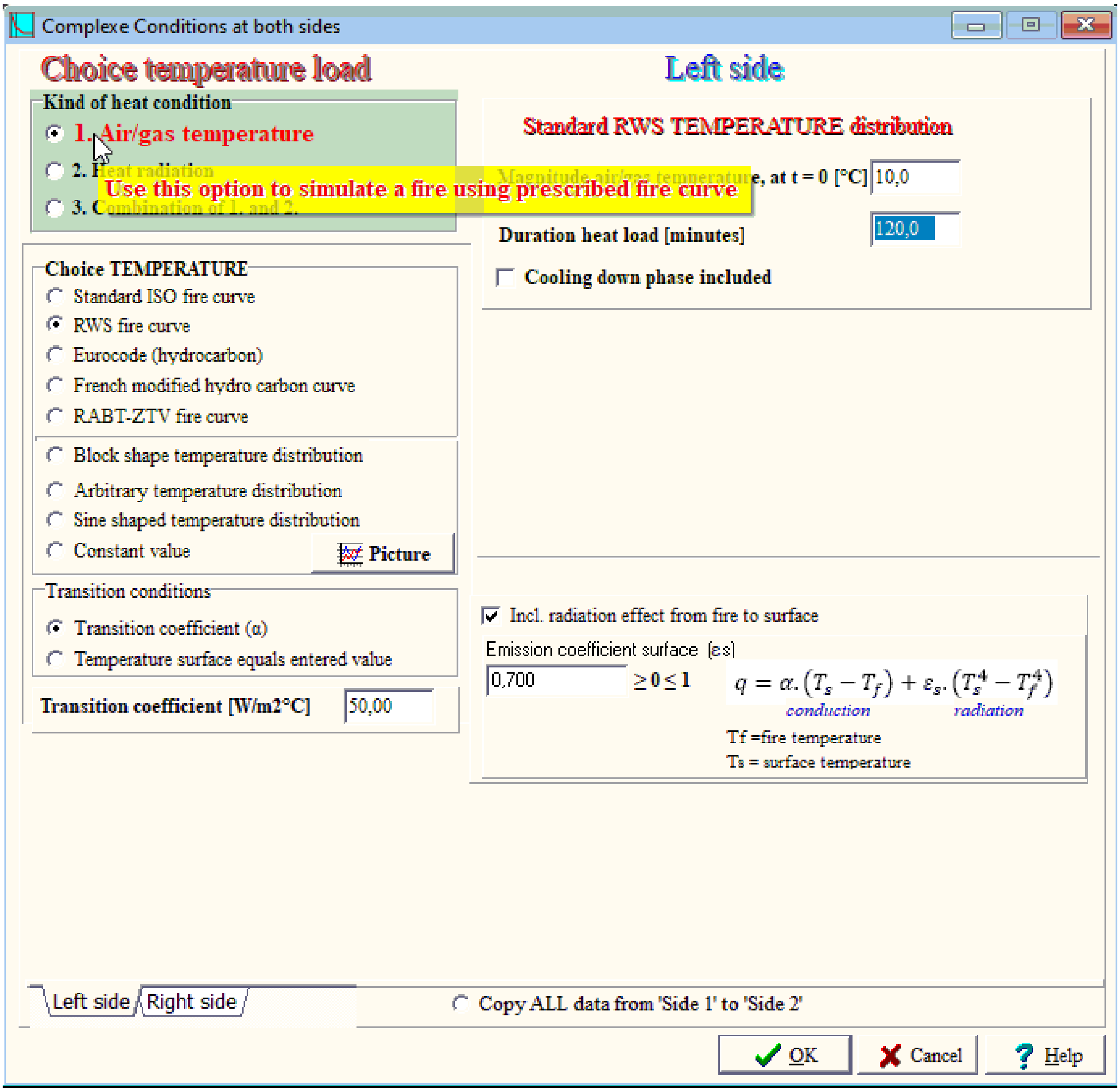
Back to the top

Conditions LEFT and RIGHT side

Conditions at the LEFT and RIGHT side

With the aid if this input window the kind and size of the heat load should be given at the LEFT and RIGHT side of the layered structure.
The input window possesses a certain amount of “intelligence”. Some input planes appear or disappear in function of the context and the choices been made.
From various possibilities of heat load choices have to be made with the aid of so called “radio buttons”.

In the figure beneath the main choice for the kind of heat load has to be made by clicking at the **green plane** on the left top side of the window.
The most common is that of option 1: "Air temperature"; the other 2 options are included for special purposes

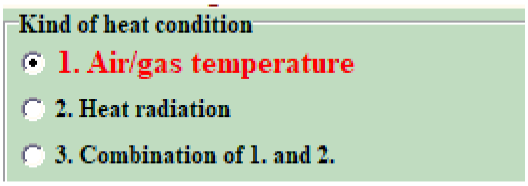


With the aid of the two tab sheets  the choice can be made between the Left and Right side.

Attention !!

The total duration of the heat load present has not to be the same as the largest point in time for which output is wanted; see at Control parameters.
The total "job time" is allowed to be less or larger than the prescribed duration of the heat load present at the left border of the structure.
Below will be mentioned how the program, per kind of border condition, treats a total "job time" larger than the duration of the heat load.

Choice of kind of heat load

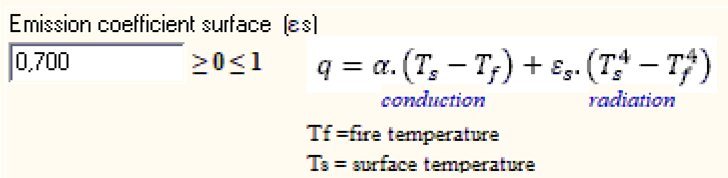


The choice is between a prescribed air temperature, a prescribed incoming radiation or a combination of both.
According to the choice been made various input planes or appearing or disappearing.

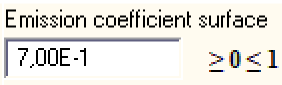
For **option 1.** the surface at the left side gets a temperature enforced via a heat transition coefficient according to a (fire)curve, which describes the air/gas temperature.

If the heat transfer takes place via ◉ Transition coefficient a radiation effect or not, in accordance with Boltzmann's law, between the difference between the flame/soot temperature and the temperature at the surface can be taken into account; see further theoretical backgrounds.

This is done by checking the box ☑ Incl. radiation effect from fire to surface or not (this choice can be different for the left and right side). By default the conduction and radiation is taken into account.



In addition, the emission coefficient for the irradiated surface ε_S



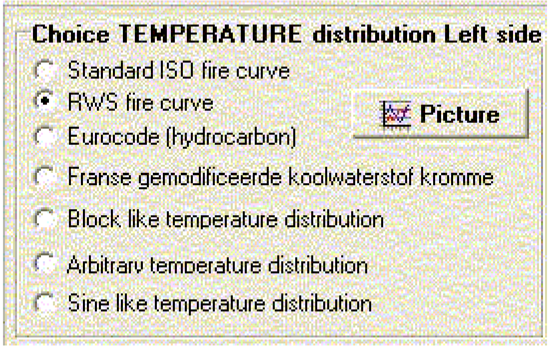
should be entered than; the default value is $\varepsilon_S = 0.7$.

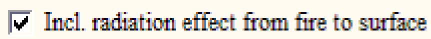
Note
In circumstances which may approximately correspond to the situation in a largely closed space like an oven, this option no. 1 should be used.
In an oven there is equilibrium between radiation from walls, roof and floor. Which means that the incoming radiation and backwards radiation is approximately into balance (no net radiation therefore to colder surroundings).
Use of option 3. under these circumstances would give a too low heat penetration.

For **option 2.** the surface at the left side receives a radiation load, which will be partly be absorbed and partly radiated backwards to the surroundings, as a function of momentary temperature at the surface (according to the law of Stefan-Boltzmann).

For **option 3.** the effects of the options **1.** and **2.** are combined. Through the presence of backwards directed radiation at option 3. it's possible that the temperature at the left surface, notwithstanding that an incoming radiation load has been entered, will be lower than the values according to the chosen curve for the air temperature (don't use this option for conditions that are broadly consistent with the closeness of an oven or tunnel).

Choice kind of TEMPERATURE load



If only a temperature boundary condition is present, no heat radiation is reflected back to the free colder space; however, if the option 

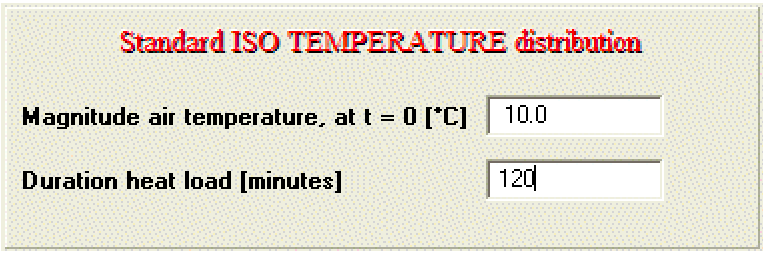
is checked, radiation transfer will take place due to the temperature difference between the hot soot and the slightly less hot surface.

As seen in the figure above seven different kind of temperature loads are supported.

With the aid of the button 

a picture for checking the input can be shown.

1. Standard ISO fire curve



This is the fire curve which is used mostly for buildings.
For times after the duration of the entered time of the temperature load (see at Control parameters) the entered air temperature at t = 0 is used.

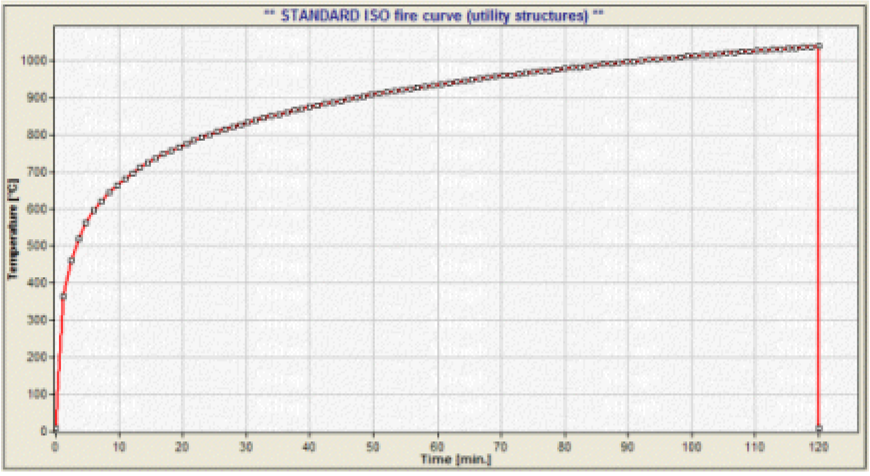
The temperature distribution as function of time is described with the formula beneath:

T = To + 345 * log(8*t+1)

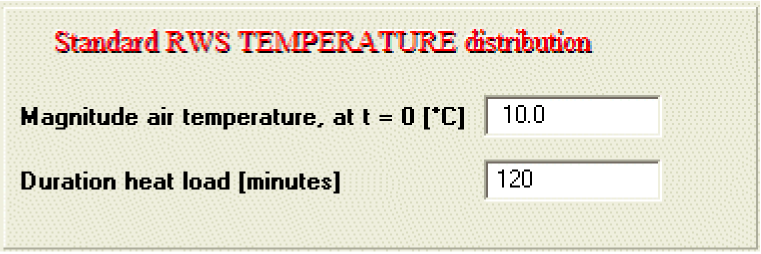
where:
T = air temperature in degrees Celsius
To = air temperature at the start; at t = “0”
t = time in minutes.

The user has next to the start temperature to enter the duration of the heat load.

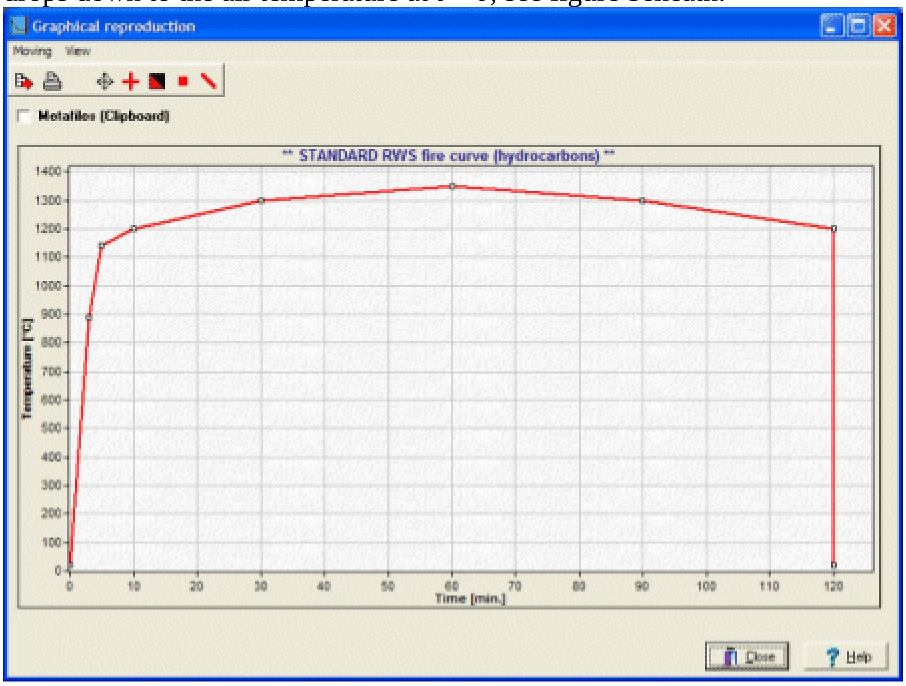
This fire curve stays climbing gradually for increasing times; see figure beneath:



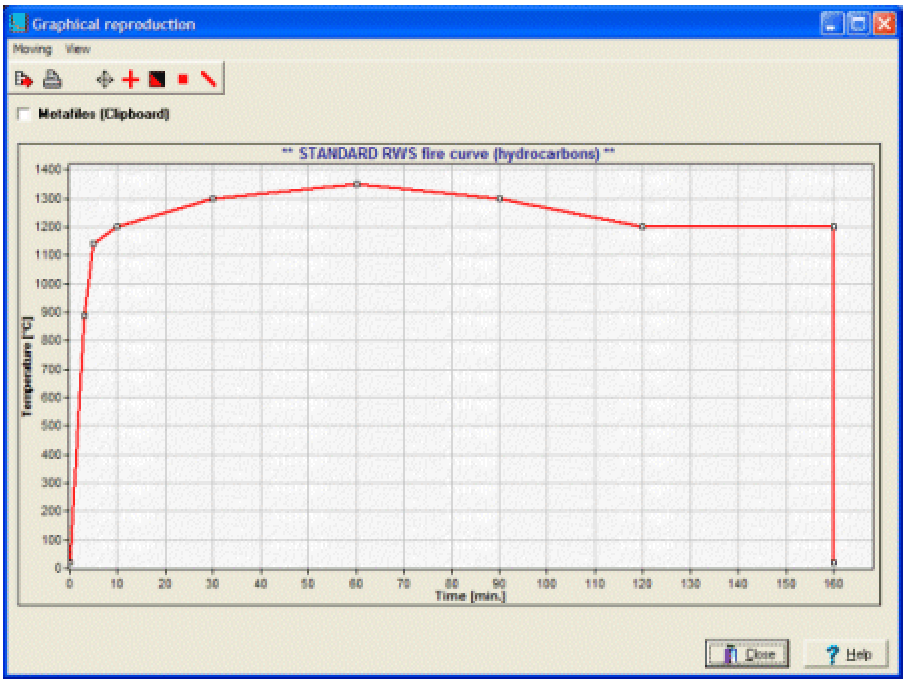
2. RWS fire curve



This is the fire curve which is handled by the Dutch government for the description of hydrocarbon fires in road tunnels.
The curve is standardized for a total duration of 120 minutes (2 hours).
If the user enters a duration of the fire equal or smaller than 120 minutes the temperature of the fire curve drops down to the air temperature at t = 0; see figure beneath:



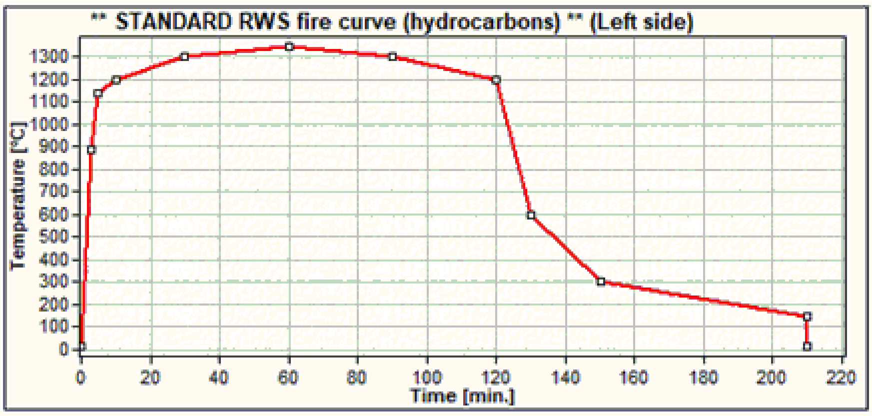
If the user enters a duration of the fire larger than 120 minutes then for points in time larger than 120 minutes a constant temperature of 1200 °C is applied by the program., after which the curve drops down again to the air temperature at t = 0; see figure beneath (total duration = 160 min.):



Time [min.]	Temperature [°C]
0	Temperature of surroundings
3	890
5	1140
10	1200
30	1300
50	1350
90	1300
120	1200

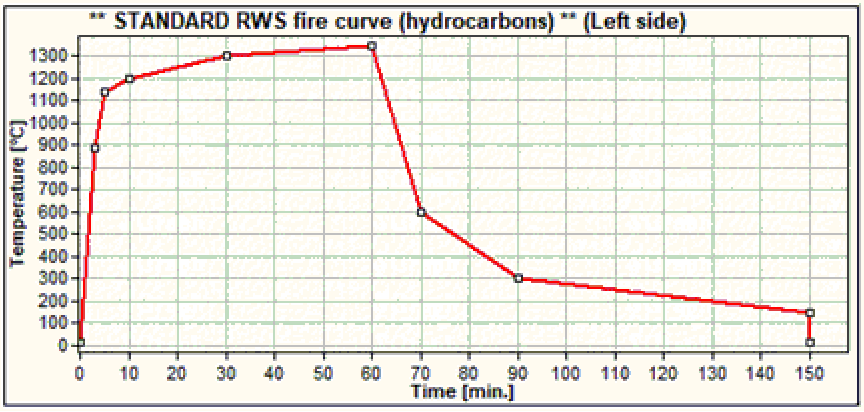
Temperatures as defined by the RWS fire curve

If the box ☑ **Cooling down phase included** is checked, a cooling process is completed at the end of the RWS fire curve shown above.
After 10 minutes, the temperature has dropped to 600 ºC; after 30 minutes to 300 ºC and after 90 30 minutes to 150 ºC



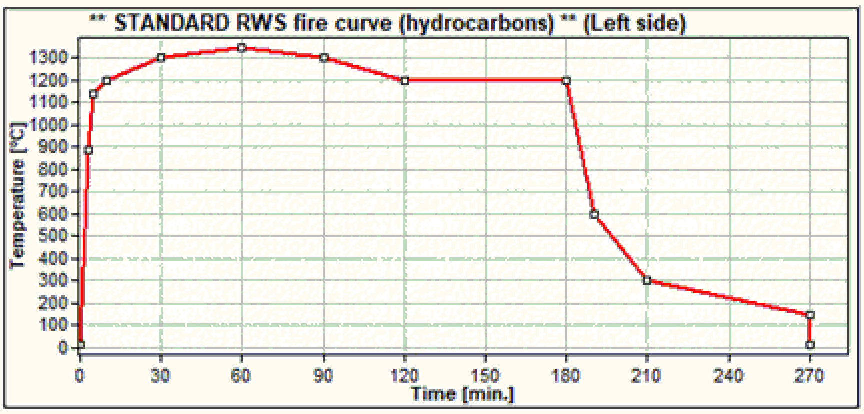
Pay attention!
If a value of less than 120 minutes is entered in the input box

Duration heat load [minutes] 60 , the cooling phase takes place from this earlier time.



If a value greater than 120 minutes is entered in the input box

Duration heat load [minutes] 180 the cooling phase takes place from this later time.
In addition, the temperature is kept constant at 1200 ºC between 120 minutes and the entered time.



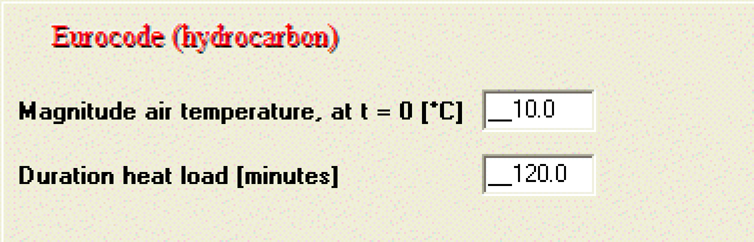
For times after the duration of the entered time of the temperature load (see at Control parameters) the entered air temperature at t = 0 is used.

Number of points in time for output

Nr.	Point of time [min
1	1,00E+1
2	2,00E+1
3	3,00E+1
4	4,50E+1
5	6,00E+1
6	9,00E+1
7	1,20E+2
8	1,80E+2
9	3,00E+2

In order for the cooling process to come into its own, the total time to be entered must be equal to or greater than "*Duration heat load*" + 90 minutes; e.g. ≥ 120 + 90 = 210 minutes.

3. Standard EUROCODE fire curve (hydrocarbons)



For times after the duration of the entered time of the temperature load (see at [Control parameters]) the entered air temperature at t = 0 is used.

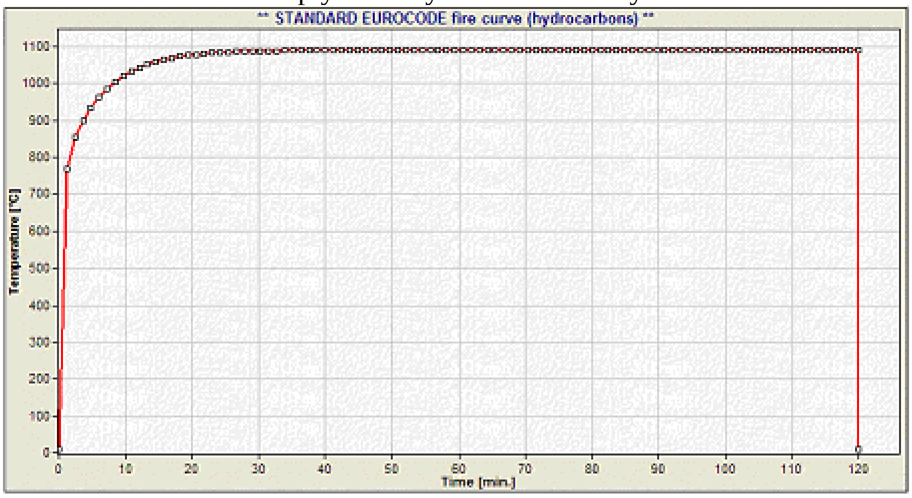
The temperature distribution as function of time is described with the formula beneath:

$$T = To + 1080 * \left(1 - 0.325 * e^{(-0.167*t)} - 0.675 * e^{(-2.5*t)}\right)$$

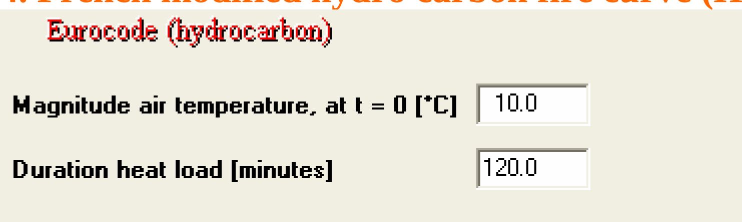
where:
T = air temperature in degrees Celsius
To = air temperature at the start; at t = “0”
t = time in minutes.

The user has next to the start temperature to enter the duration of the heat load.

This fire curve starts steeply and stays after that nearly constant.



4. French modified hydro carbon fire curve (HCM)



For times after the duration of the entered time of the temperature load (see at [Control parameters]) the entered air temperature at t = 0 is used.

The temperature distribution as function of time is described with the formula beneath:

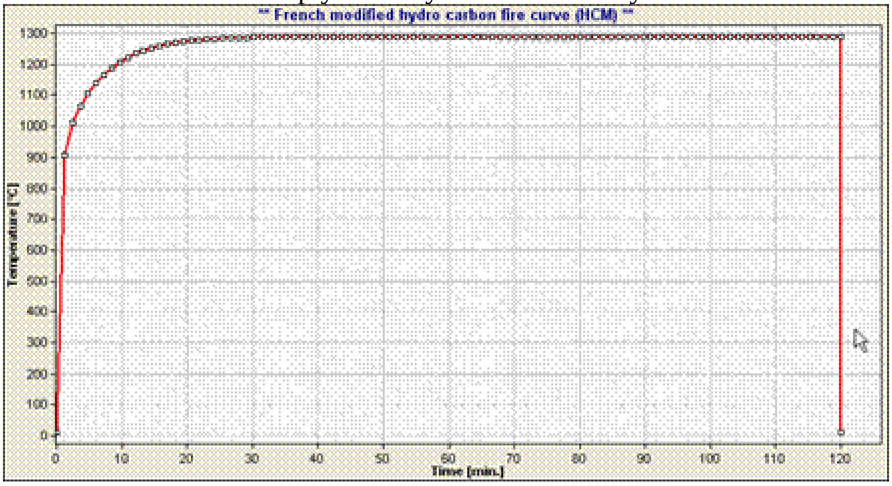
$$T = To + 1280 * \left(1 - 0.325 * e^{(-0.167*t)} - 0.675 * e^{(-2.5*t)}\right)$$

where:
T = air temperature in degrees Celsius

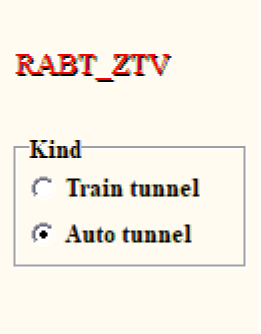
To = air temperature at the start; at t = "0"
t = time in minutes.

The user has next to the start temperature to enter the duration of the heat load.

This fire curve starts steeply and stays after that nearly constant.

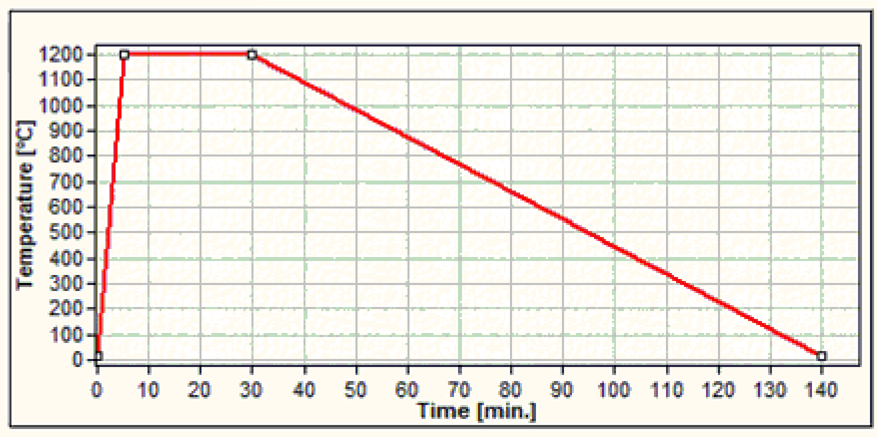


5. RABT-ZTV fire curve

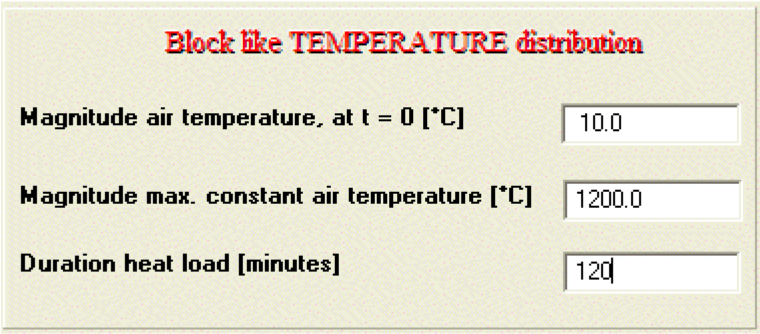


RABT-ZTV (train)	
Time (minutes)	Temperature (°C)
0	15
5	1200
60	1200
170	15

RABT-ZTV (car)	
Time (minutes)	Temperature (°C)
0	15
5	1200
30	1200
140	15

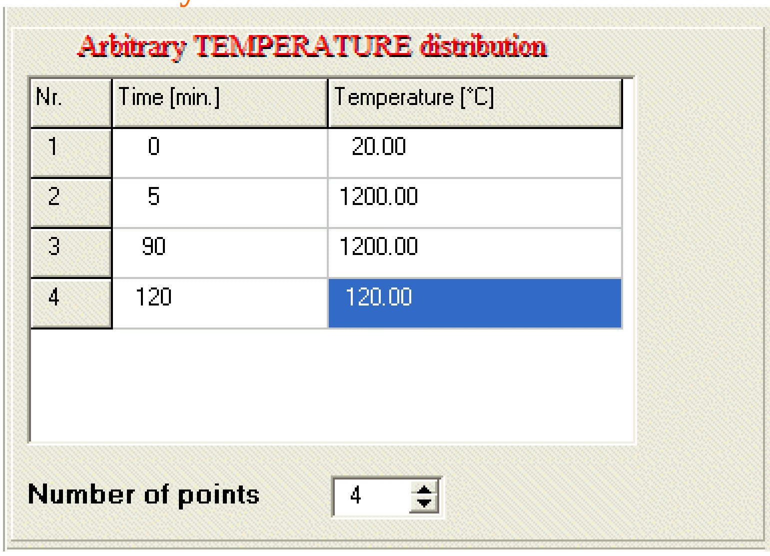


6. Block like temperature distribution

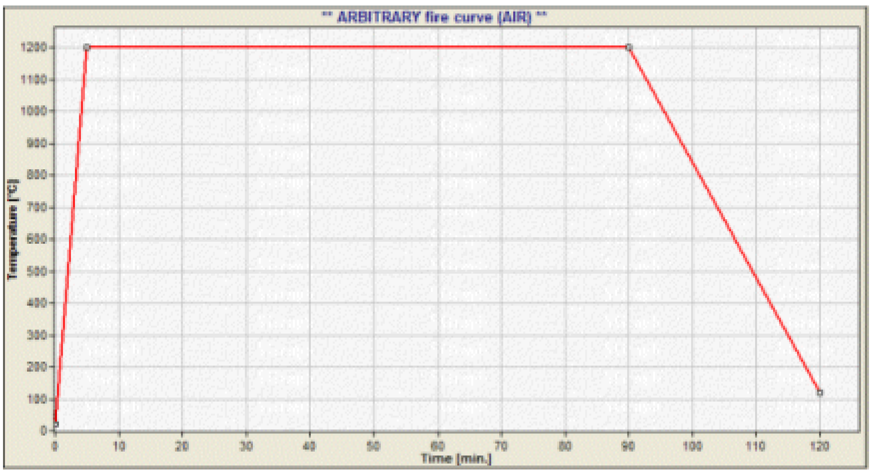


At this option during a certain time a constant temperature is present.
For times after the duration of the entered time of the temperature load (see at Control parameters) the entered air temperature at t = 0 is used.

7. Arbitrary time distribution

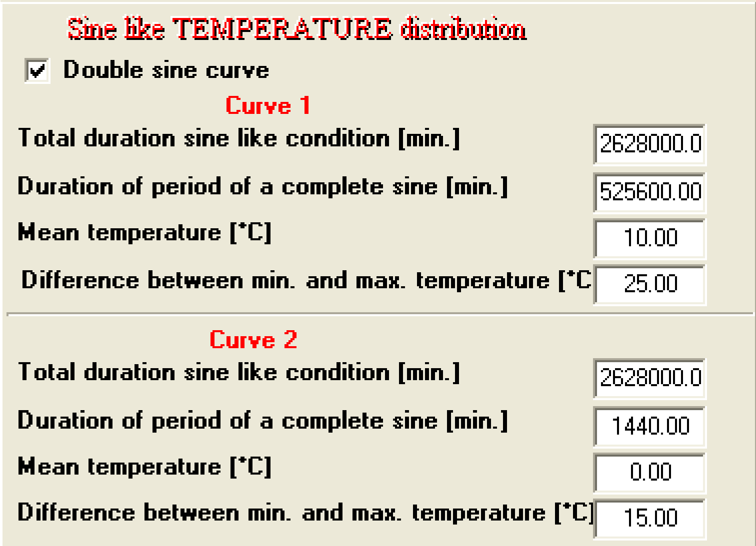


This option is the most universal way of entering the temperature distribution.
The fire curve is defined by an arbitrary number of input points.
At every input point the point in time (at a rising sequence) and the matching temperature has to be entered.
The entered input points are connected with straight lines (linear interpolation).
For times ***before*** the first entered temperature load (see at Control parameters) use is made of the ***first*** entered value for the temperature in the table.
For times ***after*** the last entered temperature load (see at Control parameters) use is made of the ***last*** entered value for the temperature in the table.



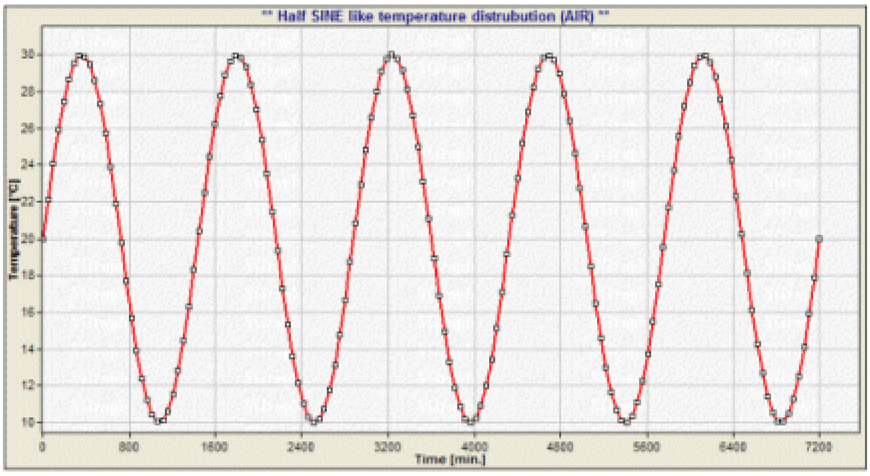
A simple example of an “arbitrary temperature distribution”

8. Sine like temperature distribution



This option is meant especially if the job at hand is not concerned with fire, but for instance the temperature changes caused by the differences of day and night.
With the aid of the checkbox the choice can be made for one or two temperature curves.

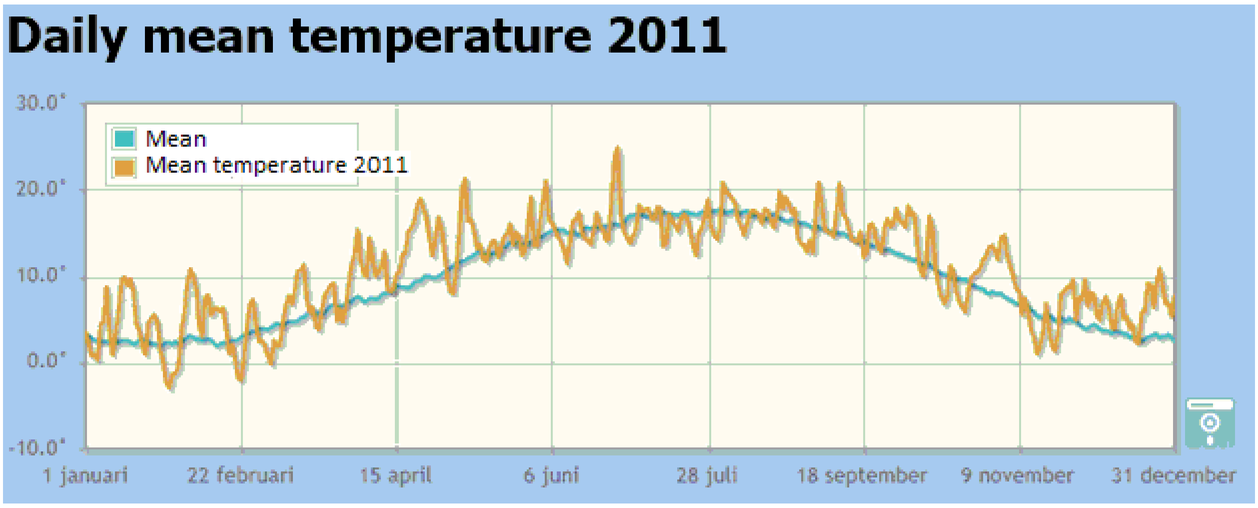
For each temperature curve the following data should be entered:
Firstly the total duration of this border condition has to be entered.
Next the duration of the period of a complete sine should be entered (1 day = 24 hours =1440 minutes).
The sine oscillates between a mean value.
Finally the difference between the maximum and minimum temperature has to be entered (two times the amplitude).



Example of the reproduction of a sine like temperature distribution.

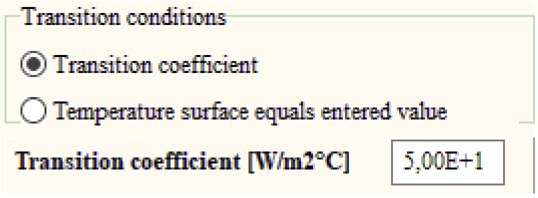
If two curves 

have been entered, the values of these two curves are added together in the calculation process.
This option can be useful if a day rhythm and a year rhythm of the outside temperature have to be calculated simultaneously.
Zoals uit onderstaand voorbeeld blijkt kan het gemiddeld temperatuurverloop over een jaar redelijk benaderd worden m.b.v. een sinusvormig verloop.
As the example below shows the average temperature variation over a year can be reasonably approximated using a sinusoidal gradient.



For times after the duration of the entered time of the temperature load (see at Control parameters) the entered mean temperature is used.

Choice of the transition condition



The TEMPERATURE load can act at two different ways at the surface of the first layer (LEFT side).

1. Via a transition coefficient

If the entered temperature distribution describes the air temperature next to the structure, then the temperature direct at the surface of the structure is somewhat lower.
A kind of transition resistance is present.

For a **fire load** the heat transition coefficient is rather effective because turbulence effects (**α** = 25 á 75 [W/m^2.°C]).
In NEN-EN 1991-1-2 the following is mentioned in art. 3.2:
3.2.1 Standard fire curve
α = 25 [W/m2.°C]
3.2.2 Curve for an external fire
α = 25 [W/m2.°C]
3.2.3 Hydrocarbon curve
α = 50 [W/m2.°C]

At **normal climate temperatures** the two formulas beneath are sometimes used to calculate the value for then transition coefficient **α** [W/m^2.°C].

$\boldsymbol{\alpha = 5{,}55 + 3{,}9 * V}$ for V <= 5 m/s

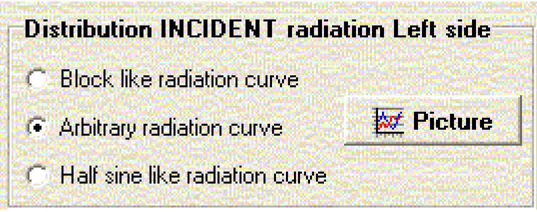
$\boldsymbol{\alpha = 7{,}1 * V^{0{,}78}}$ for V > 5 m/s

where
V = velocity of the wind in m/s
At higher velocities of the wind the heat transport is more efficient (it seems colder if the wind blows strongly).
Also for temperatures belonging to a fire the heat transport is rather efficient (**α** = 50 á 100 [W/m^2.°C]).

2. Temperature at the surface equals exact the entered values.

If for this option is chosen there is no difference between the air temperature and the surface temperature.
This option can only be used if no radiation as border condition is present !!!

Choice kind of radiation load



If radiation is part of the left side condition, whether or not in combination with a described temperature curve, at the surface the law of Stefan-Boltzmann does apply:

$$q_r = \varepsilon.\sigma.\left(T_w^4 - T_o^4\right)$$

where:

q = heat flux [kW/m^2]

σ = Stefan-Boltzmann constant = 5.67051E-8 [W/(m^2.°C)]

ε = emission coefficient ≅ absorption coefficient

T_w = temperature at wall (at the LEFT side) [°K]

T_o = temperature of the surrounding where will be radiated backwards [°K]

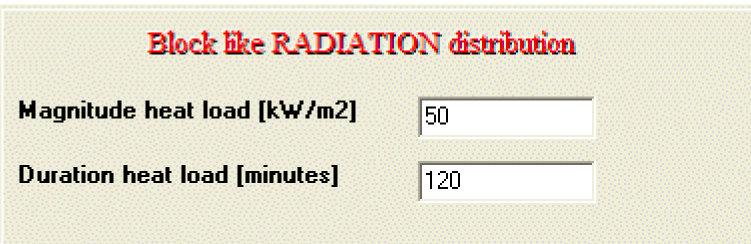
The last temperature has to be entered into the box depicted below.

If the checkbox above has not been checked the entered radiation load will not be corrected by the back radiation according Stefan-Boltzmann.
The effect of backwards radiation is that the temperature at the surface will increase slower as function of time, because the backwards radiation at higher temperatures will approach the given incoming radiation.

With the aid of the button 

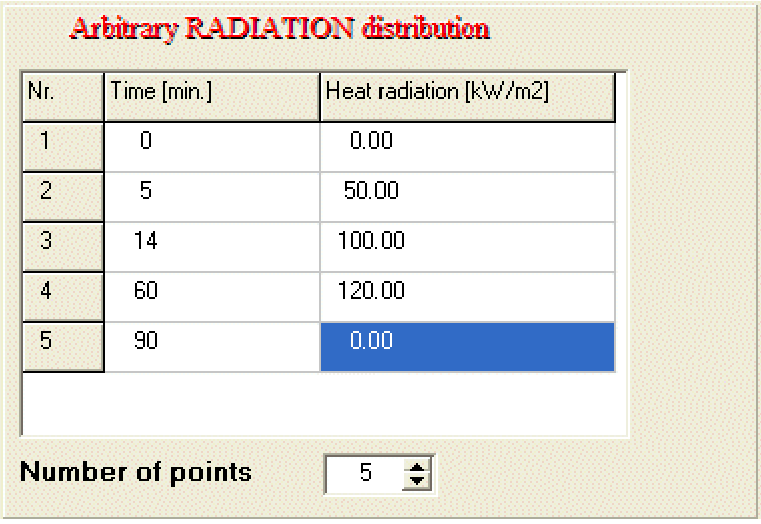
for the purpose of checking a picture can be made of the entered data.
At this point of choice for the kind of radiation three input possibilities are present:

1. Block like radiation curve

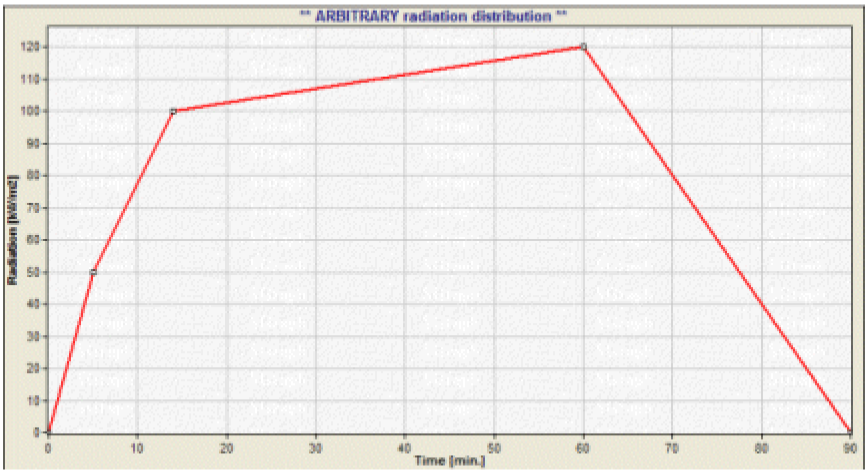


For this option during a certain time the radiation load is constant.
For times later then the entered duration of the radiation load (see at Control parameters) the amount of radiation is zero.

2. Arbitrary radiation curve

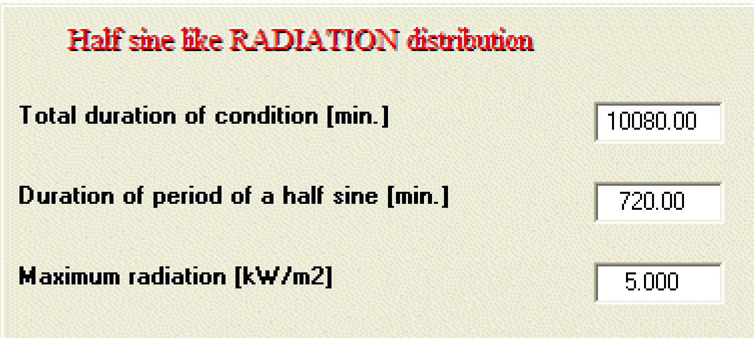


This option is the most universal way of input for the radiation distribution.
The radiation curve is defined by an arbitrary amount of input points.
At every input point the point in time (at a rising sequence) and the matching radiation load [kW/m^2] has to be entered.
The entered input points are connected with straight lines (linear interpolation).
For times after the entered total duration of the radiation load (see at Control parameters) the amount of radiation is zero.



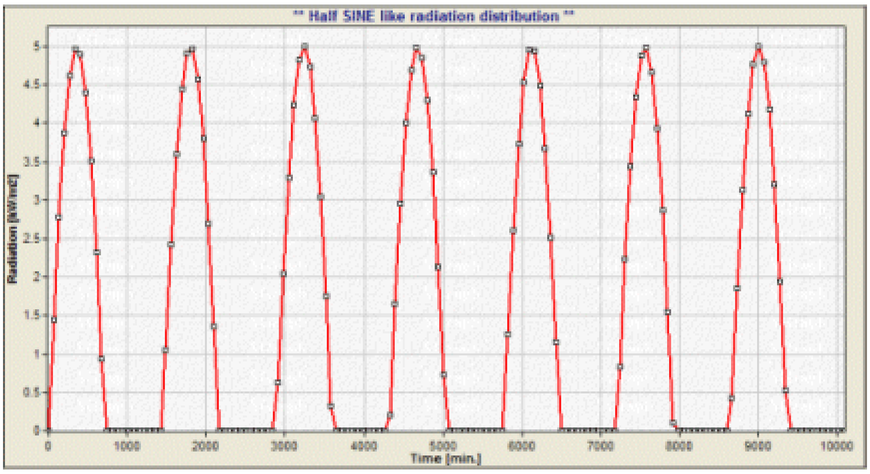
A simple example of an “arbitrary radiation distribution”

3. Half sine like radiation curve



This option is primarily meant for applying to other then fire related calculations; e.g. the penetration of temperature changes caused by the differences between day and night.
For this option the radiation from the sun during the day-time is dealt with according to a sine like distribution; at night the incoming radiation equals zero.
For times after the entered total duration of the radiation load (see at Control parameters) the amount of

radiation is zero.



An example of a “half sine like” distribution of the heat radiation

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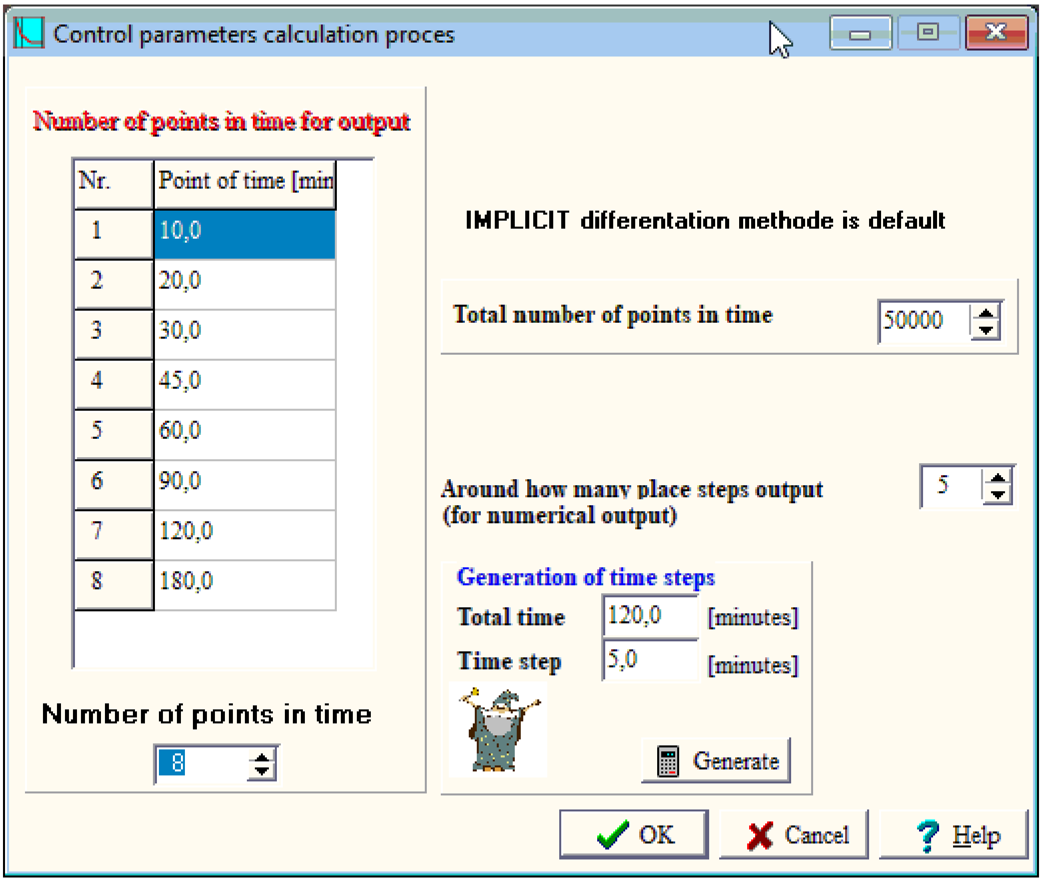
Control parameters

Control parameters

With this input window the distribution of the calculation process can be controlled; see figure beneath:



Number of points in time for output

Here should be entered at how many time steps and on which points in time numerical as well as graphical output is wanted.
The entered times should have a rising distribution in time.

Attention !!

The total duration of the heat load present has not to be equal with the maximum point in time where output is wanted; see also conditions at the LEFT and RIGHT side.
The total "job time" is allowed to be shorter than the entered duration of heat load present at the left border.

Generation of time steps

This option can help generate the number of times for which output is desired.

Total number of points in time

The total time of the calculation process have to be divided into a number of steps.
The number of time steps decides the attained accuracy of the calculation.
Next to time steps the structure is divided into place steps; this happens automatically however.
The number of handled place steps is shown at the numerical output.

Because of the applied implicit calculation method the stability of the calculation process is unconditionally guaranteed.

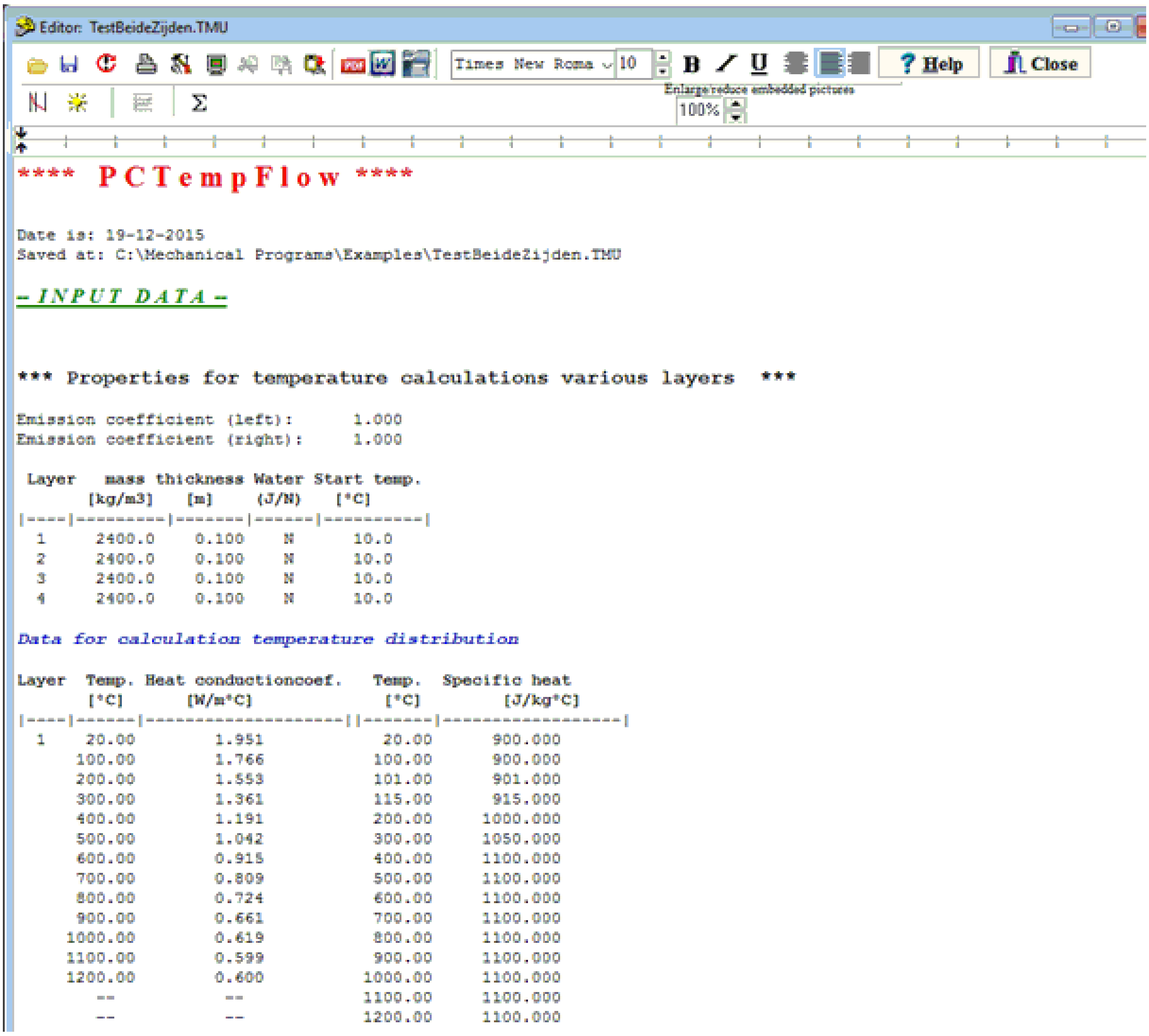
Around how many place steps output

In order to prevent a very voluminous numerical output here can be entered at how many steps numerical output should is wanted.
If the number 1 is entered every place step is shown at the numerical output.
With for instance a number of 5 ca. 20 % of the number of place steps present is shown.
At the transition of the layers numerical output always is shown.

Echo of the input data

Echo of input data

With this menu option an editor window opens in which all input data is shown; see example beneath:


Editor: TestBeideZijden.TMU

**** PCTempFlow ****

Date is: 19-12-2015
Saved at: C:\Mechanical Programs\Examples\TestBeideZijden.TMU

-- INPUT DATA --

*** Properties for temperature calculations various layers ***

Emission coefficient (left): 1.000
Emission coefficient (right): 1.000

Layer	mass [kg/m3]	thickness [m]	Water (J/N)	Start temp. [°C]
1	2400.0	0.100	N	10.0
2	2400.0	0.100	N	10.0
3	2400.0	0.100	N	10.0
4	2400.0	0.100	N	10.0

Data for calculation temperature distribution

Layer	Temp. [°C]	Heat conductioncoef. [W/m°C]	Temp. [°C]	Specific heat [J/kg°C]
1	20.00	1.951	20.00	900.000
	100.00	1.766	100.00	900.000
	200.00	1.553	101.00	901.000
	300.00	1.361	115.00	915.000
	400.00	1.191	200.00	1000.000
	500.00	1.042	300.00	1050.000
	600.00	0.915	400.00	1100.000
	700.00	0.809	500.00	1100.000
	800.00	0.724	600.00	1100.000
	900.00	0.661	700.00	1100.000
	1000.00	0.619	800.00	1100.000
	1100.00	0.599	900.00	1100.000
	1200.00	0.600	1000.00	1100.000
	--	--	1100.00	1100.000
	--	--	1200.00	1100.000

Conversion to another format

With the aid of the button the text can be converted and shown in Adobe PDF format (https://get.adobe.com/nl/reader/)

With the aid of the button the text can be shown within the Microsoft text editor WORD (https://www.microsoft.com/nl-nl/download/details.aspx?id=4)

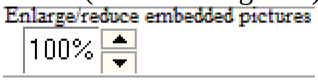
With the aid of the button the text can be shown within in OpenOffice Writer (https://www.openoffice.org/product/writer.html)

Graphical depictions in between the text

With the aid of the button the input data of the material properties of the various layers can be depicted in between the text.

With the aid of the button the input data of input data of the border conditions at the left and right side can be depicted in between the text.

With the aid of the button Σ ALL input data can be depicted in between the text ( +  together).

The size of graphical figures embedded in between the text can be adjusted: 

See further also [Numerical output data]

Output

Numerical

Numerical output

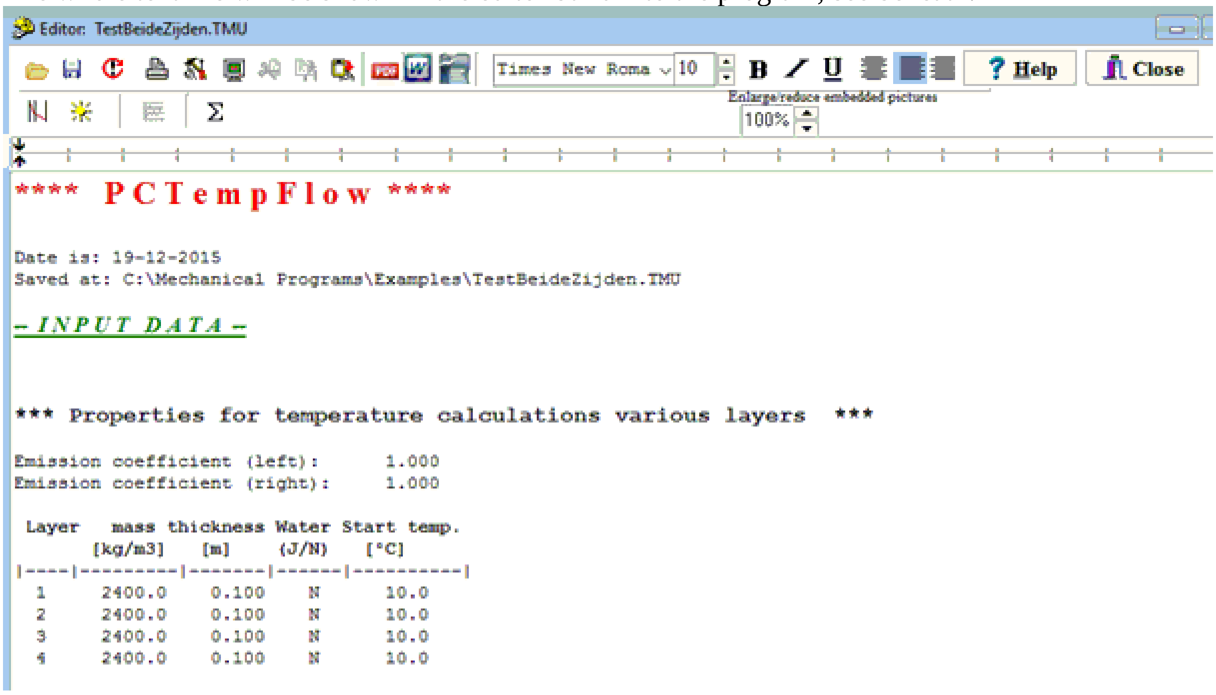
With the aid of this menu option (or speed button) the calculation results can be shown in numerical shape; see further also Graphical output

In the first part of the output an echo is given of the input data.

In the second part de calculation results will be shown:

1. across the thickness of the structure at time steps provided on beforehand; time steps have to be adjusted via Control parameters
2. at layer transitions (lest side of every layer that has been input) as function of time; the layers have to be defined via Properties of the layers

The whole text file will be shown in the editor build into the program; see beneath:



Conversion to other format

With the aid of the button the text can be converted and shown in Adobe PDF format (https://get.adobe.com/nl/reader/)

With the aid of the button the text can be shown within the Microsoft text editor WORD (https://www.microsoft.com/nl-nl/download/details.aspx?id=4)

With the aid of the button the text can be shown within in OpenOffice Writer (https://www.openoffice.org/product/writer.html)

Graphical depictions in between the text

With the aid of the button the input data of the material properties of the various layers can be depicted in between the text.

With the aid of the button the input data of input data of the border conditions at the left and right side can be depicted in between the text.

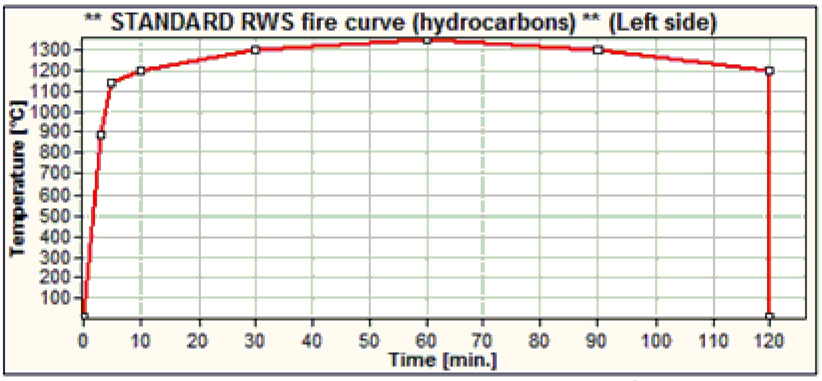
With the aid of the button the various calculation results can be depicted in between the text.

With the aid of the button Σ ALL input data can be depicted in between the text (+ + together).

The size of graphical figures embedded in between the text can be adjusted: Enlarge/reduce embedded pictures 100%

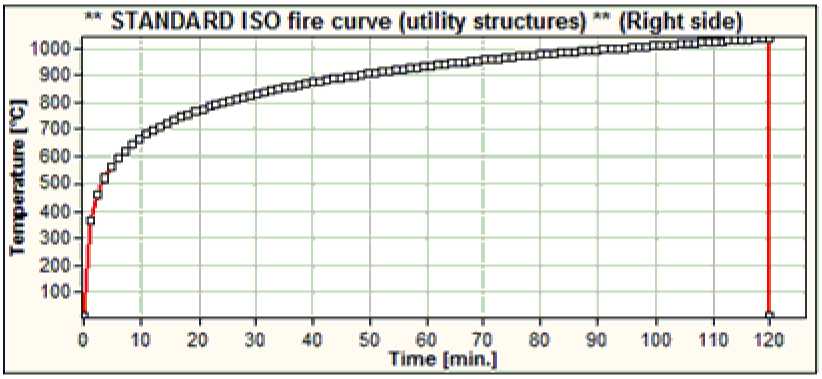
Fragment of the echo of input data (with embedded figures):

*** Conditions at SIDE 1 ***



Heat transition conduction coefficient [W/m2/°C] is: 50.0
** The distribution of the air temperature agrees with the standard RWS fire curve **
(hydrocarbon fire)
This temperature load is present during 120.0 minutes.
The air temperature for t=0 [°C] is: 10.0

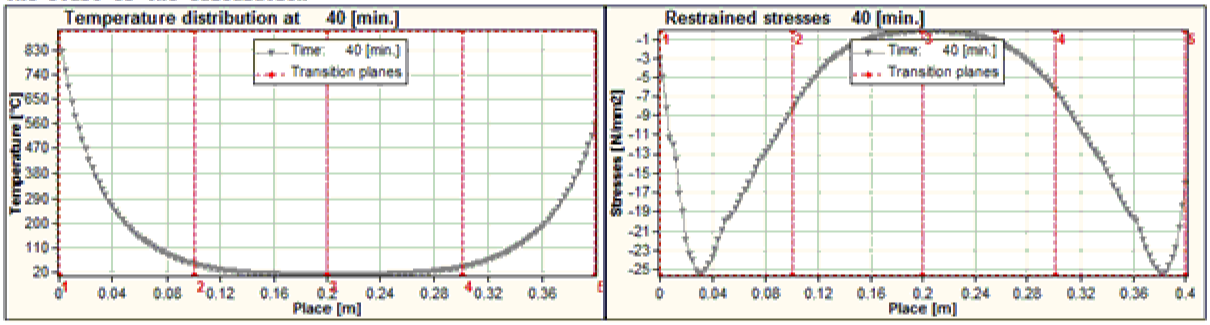
*** Conditions at SIDE 2 ***



Heat transition conduction coefficient [W/m2/°C] is: 50.0
** The distribution of the air temperature agrees with the standard ISO fire curve **
(buildings)
This temperature load is present during 120.0 minutes.
The air temperature for t=0 [°C] is: 10.0

Fragment of numerical output of calculation results (with embedded figures):

Data given beneath holds for the point in time of 40.0 minutes after the start of the calculation



Place [m]	Temperature [°C]	Stresses restrained distorsions [N/mm2]
0.000	897.67	-3.0609
0.003	821.88	-5.0438
0.005	753.54	-8.2304
0.007	692.21	-11.3471
0.010	637.16	-12.0866
0.013	587.55	-13.4736
0.015	542.79	-17.0555
0.018	502.20	-18.9732
0.020	465.29	-21.8449
0.023	431.66	-23.4511
0.025	400.88	-24.0688
0.028	372.66	-25.1792
0.030	346.74	-25.5893
0.033	322.84	-25.4677
0.035	300.76	-24.9679
0.038	280.32	-24.4771
0.040	261.40	-23.7642
0.043	243.85	-22.8905
0.045	227.55	-21.9108
0.048	212.38	-20.8662
0.050	198.25	-19.8977
0.053	185.09	-19.5881
0.055	172.84	-19.1535
0.058	161.41	-18.6213
0.060	150.75	-18.0141
0.063	140.79	-17.3506
0.065	131.48	-16.6466
0.068	122.79	-15.9152

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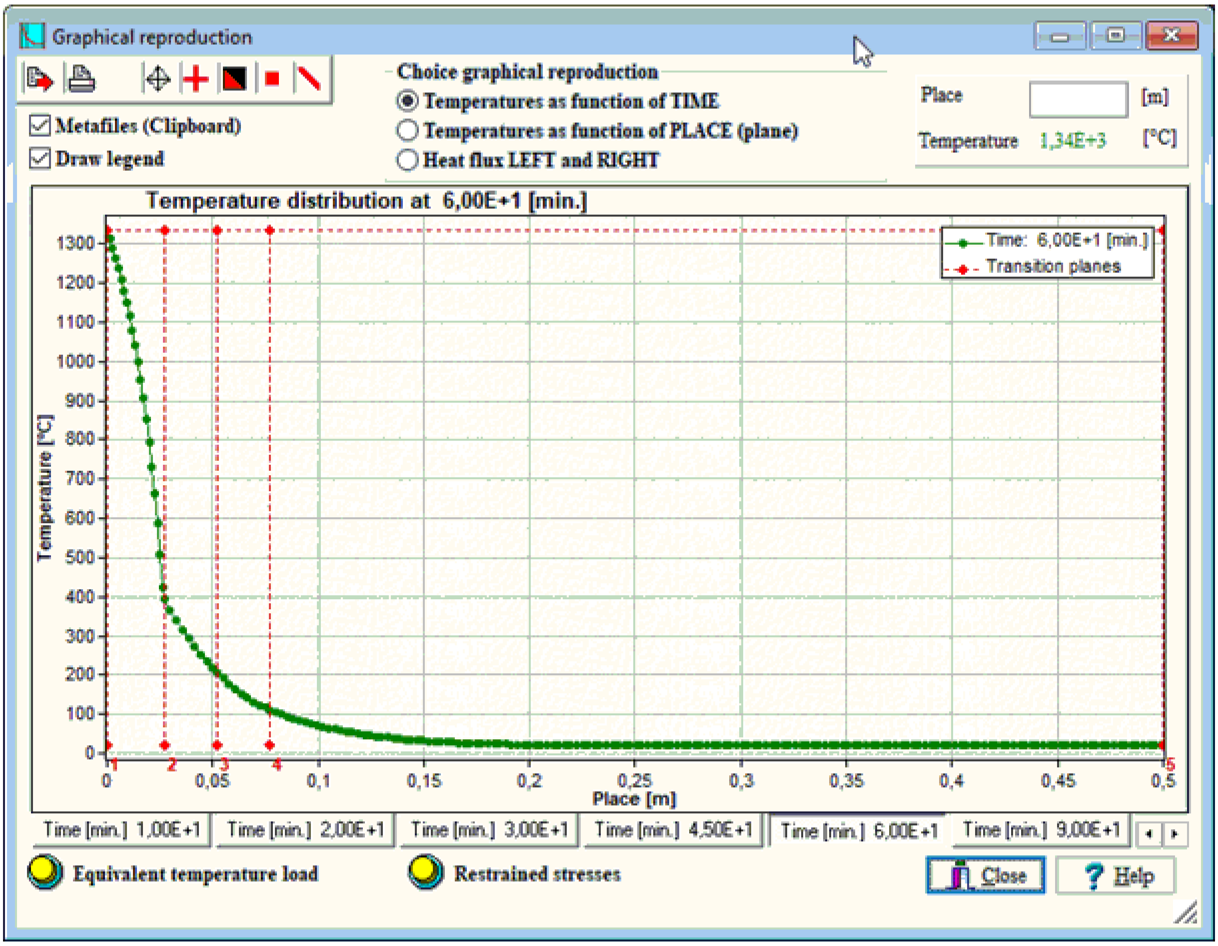
Graphical

Graphical output

Next to the numerical reproduction of the calculation results (Numerical) the results can also be show graphically.
On the concerning screen the results can be pictured at two different ways:
 1. across the thickness of the structure at fixed points in time; points in time can be setup via Control parameters
 2. at transition planes (left side of each entered layer) as function of time; layers can be setup via Properties of layers
 3. the heat flux at the surface at the LEFT and RIGHT side

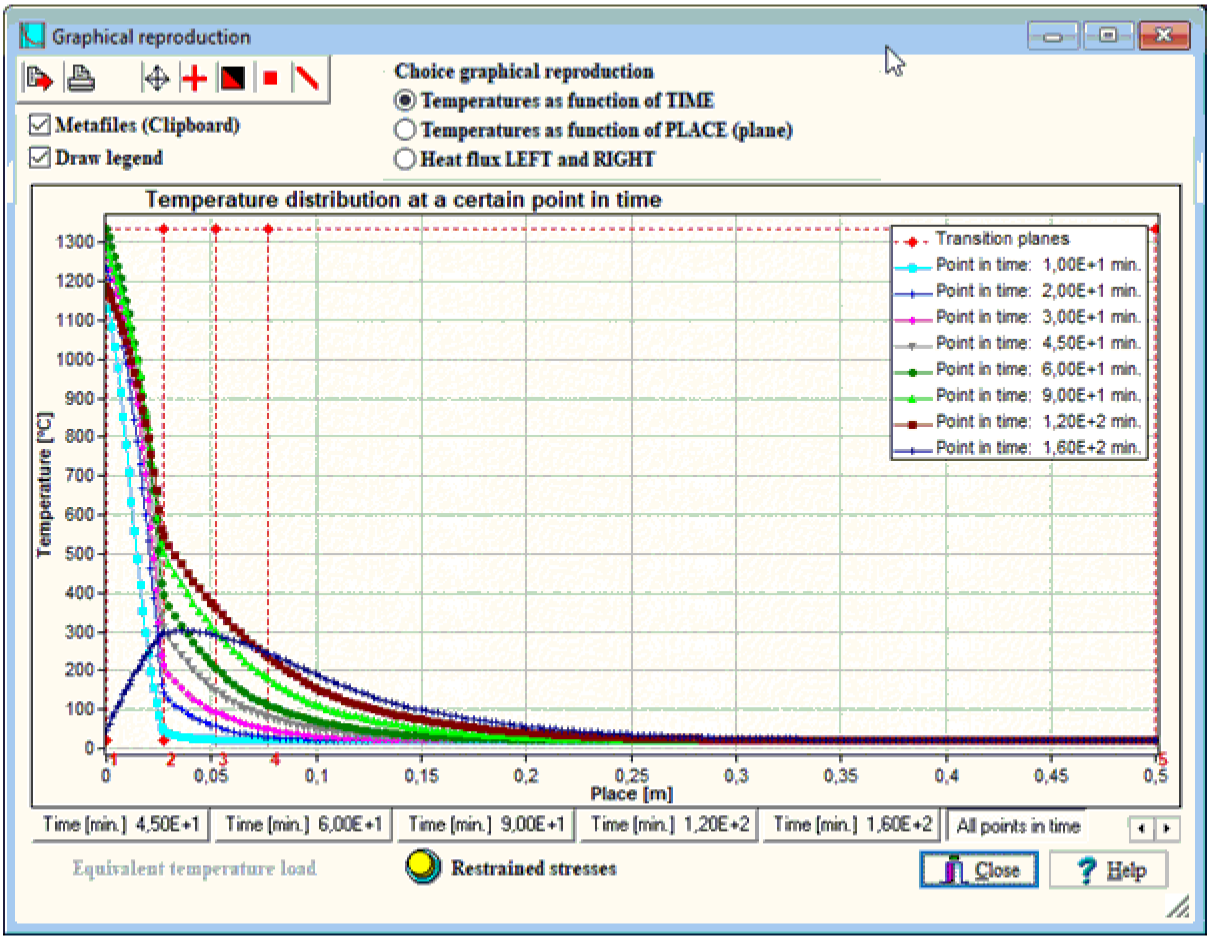
ad. 1.: See examples beneath:



Temperature distribution as a function of the place at a specific time

Via the control buttons at the bottom the various points in time can be chosen at which the temperature distribution in the direction of the thickness will be shown.
At the horizontal axis the distribution in the direction of the thickness of the layered structure is shown; in meters.
The vertical axis depicts the temperature distribution; in degrees Celsius.
De depicted maker points concerns only a selection of the handled “place points” used in the calculation process.
Via the green radio buttons above a choice can be made between reproduction option **1.**, **2.** or **3.**
The vertical numbered and coloured lines in red gives the locations of the transition planes, at those places with option **2.** output as function of the time can be acquired.
The last control button at the right bottom side of the screen pictures all the lines together; see picture

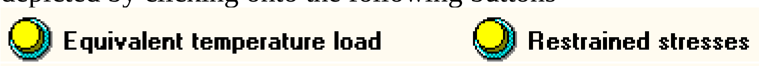
beneath:

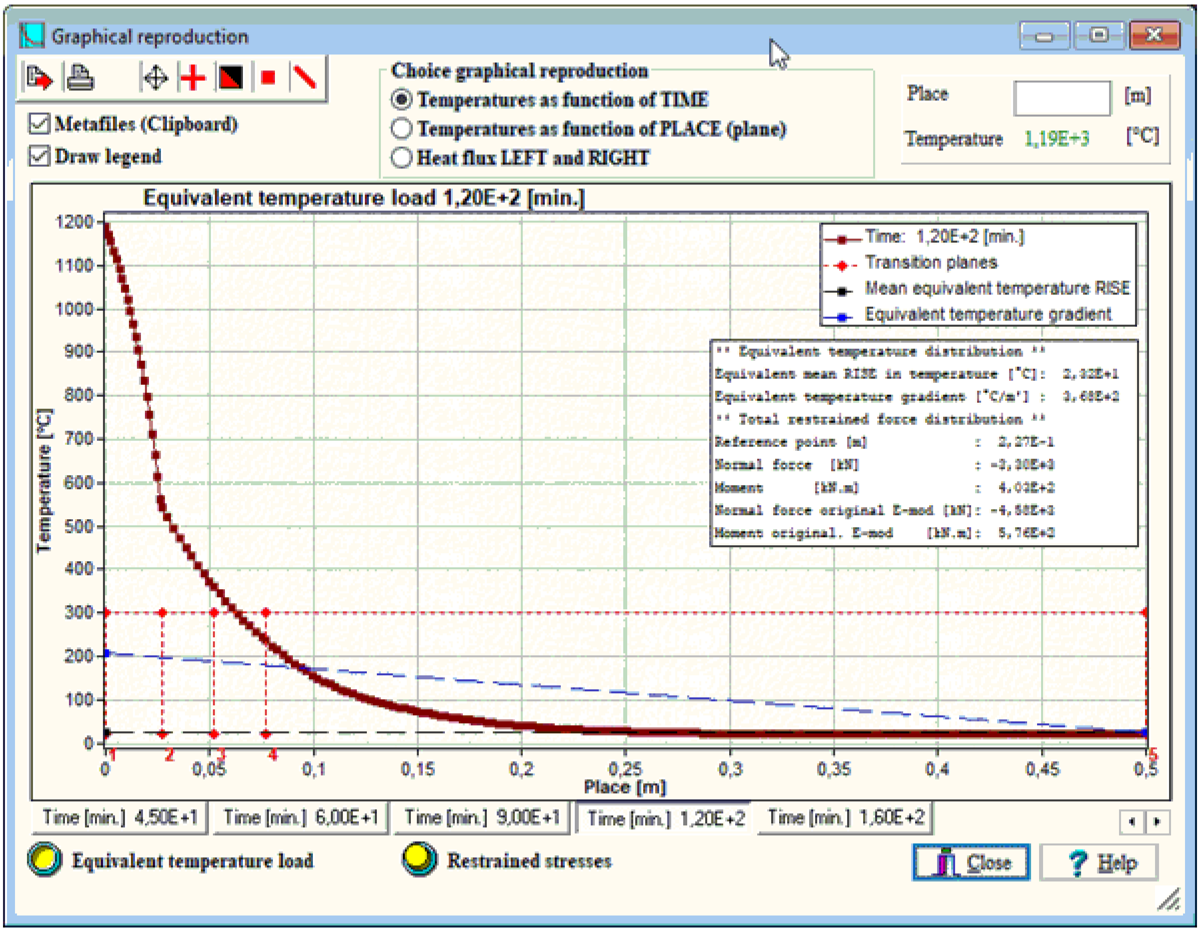


Temperature distribution as function of the place for a number of steps in time

If at the input of [properties of layers]() at the 2e tab sheet, at 

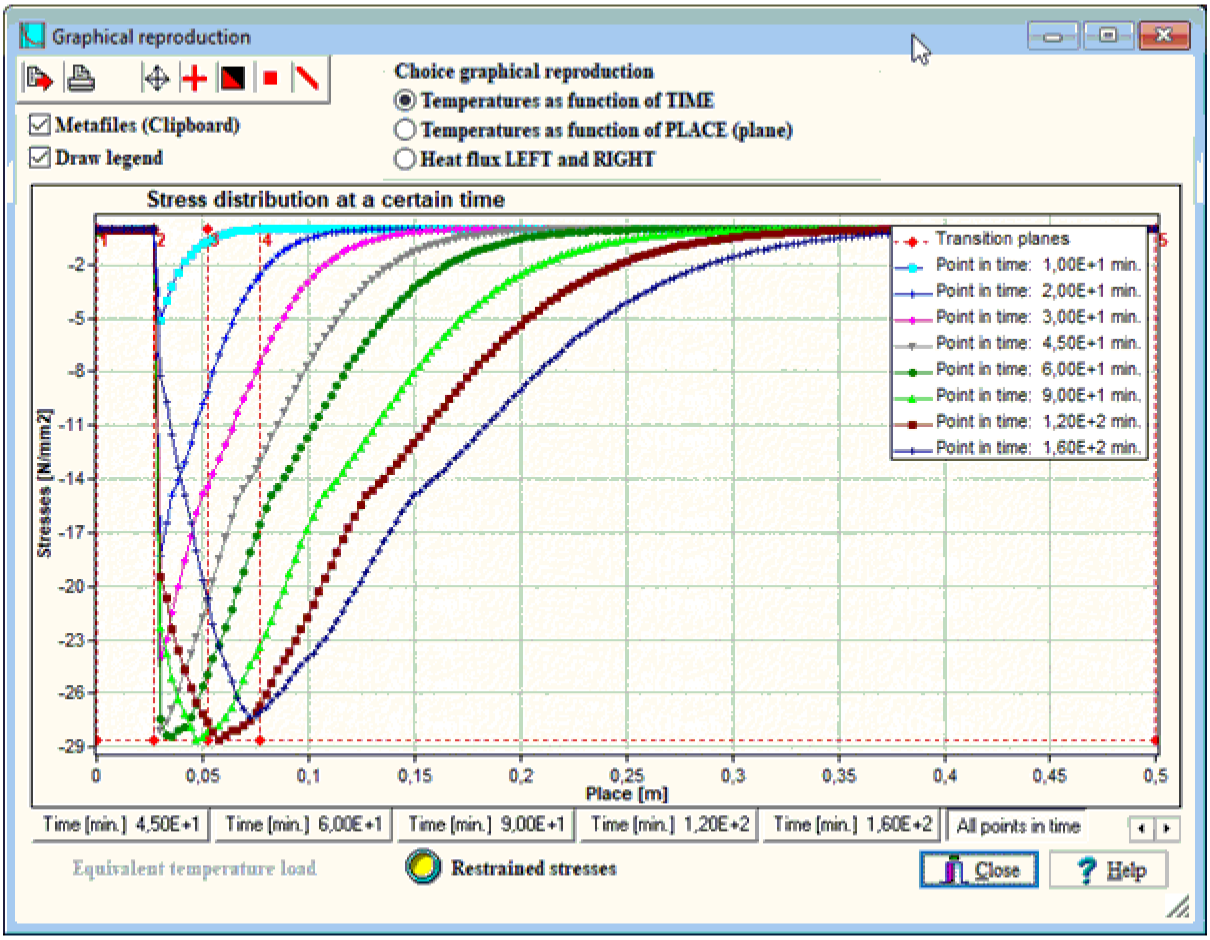
, the choice has been made for the calculation of the linear distributed temperature load the results can be depicted by clicking onto the following buttons





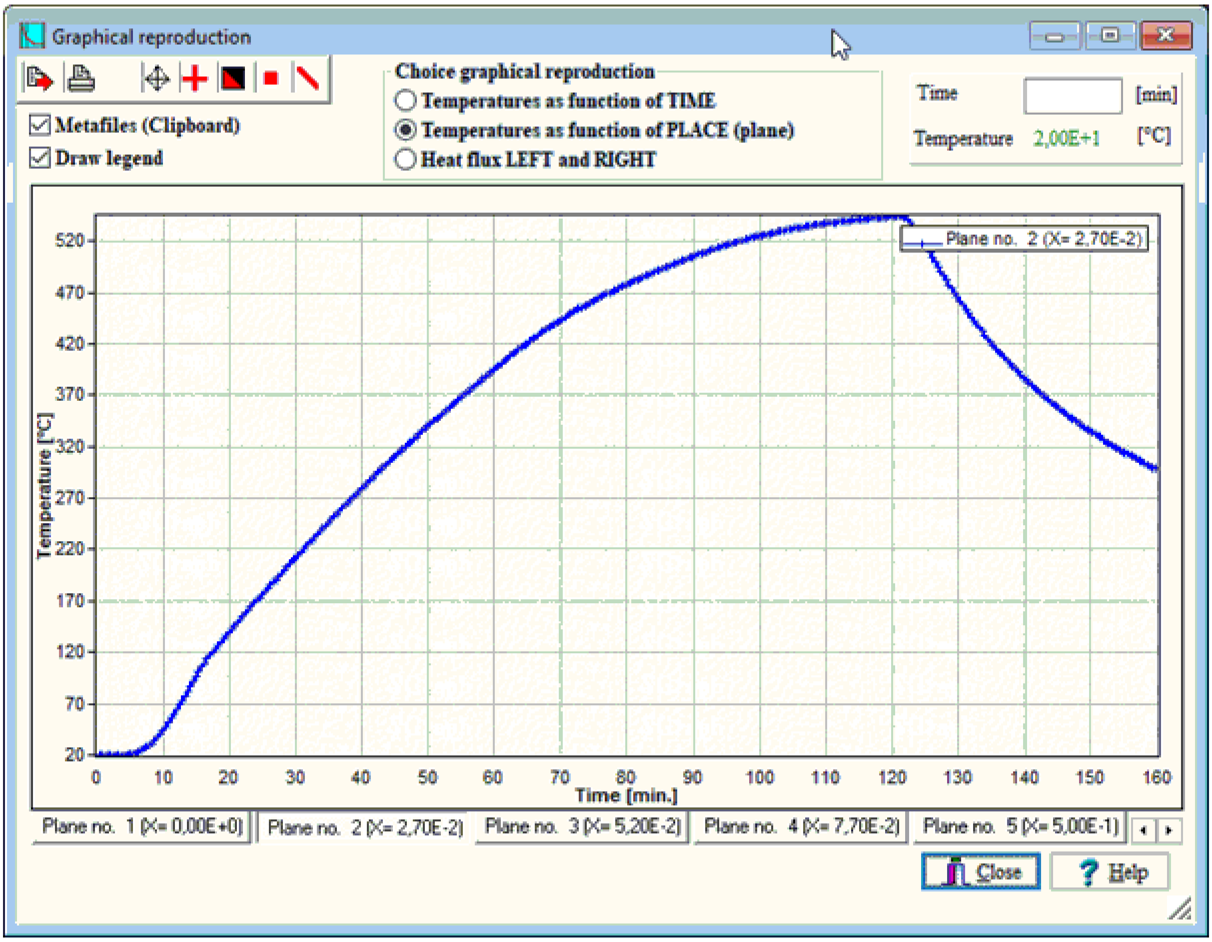
Actual and linear equivalent temperature distribution
*(mean temperature **rise** and temperature gradient).*

Using the ***equivalent*** mean temperature and gradient as input in a framework program (using the value for the E-modulus at 'normal' temperatures [20°C]) calculates the same force distribution in the frame as the true non-linear temperature distribution at a given time .
The program Framework does support the input and calculation of temperature beam loads for instance.
This should be calculated for the time-step with the maximal equivalent linear temperature distribution to find the maximal effect for the structure of course.
Because the regarding beam(s), loaded with equivalent temperature loads, are part of a frame structure both sides of the beam(s) can have various levels of 'restrainment'.



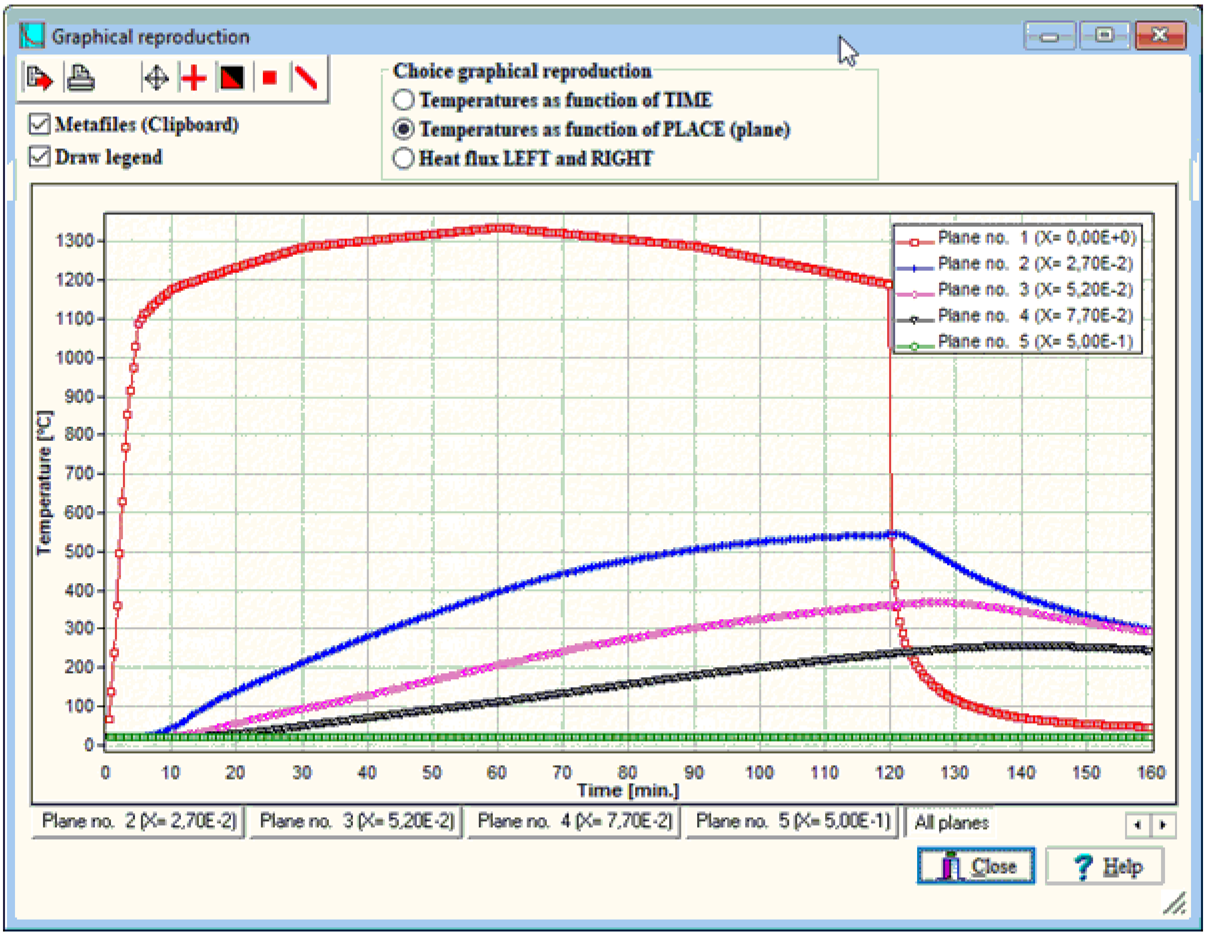
Restrained stress distributions caused by the actual temperature distribution

ad. 2.: See examples beneath:



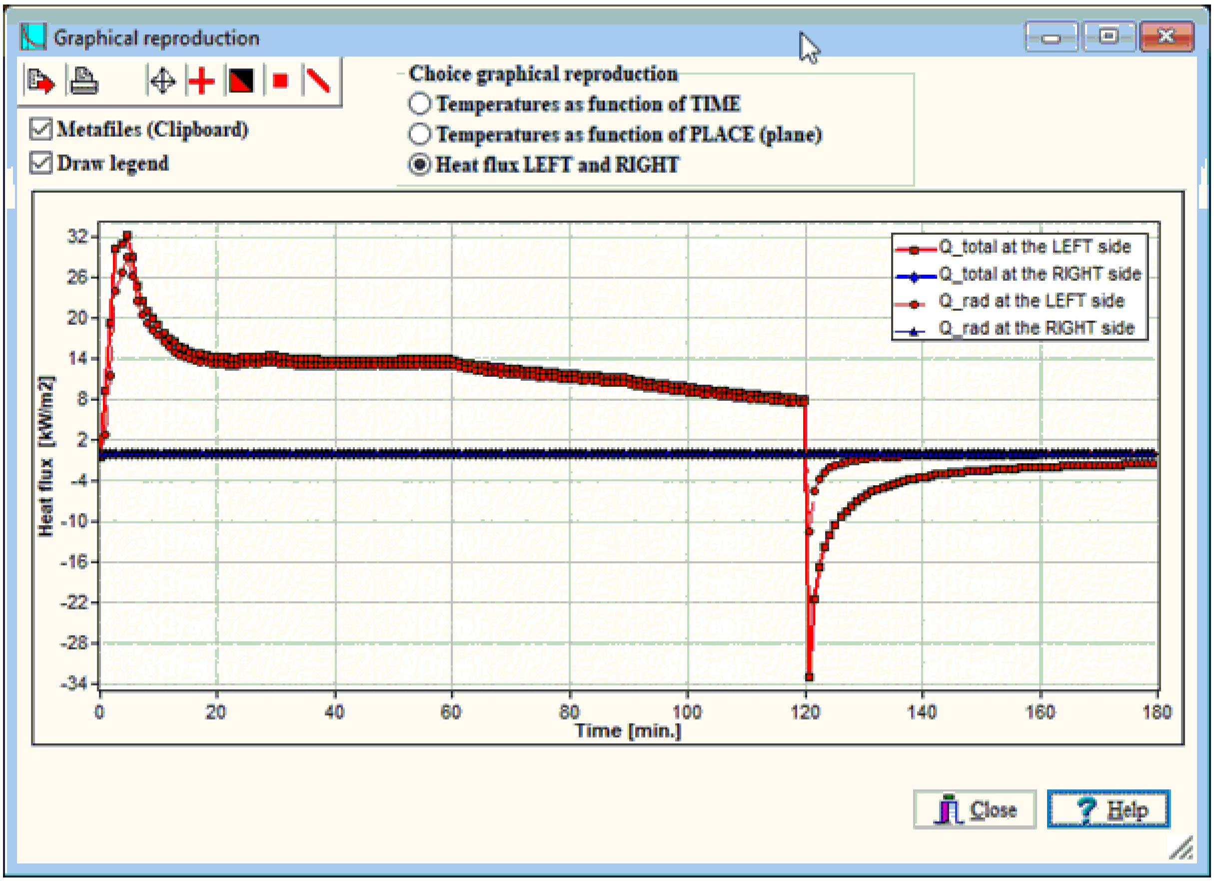
Temperature distribution as function of the time at a certain place

Via the control buttons at the bottom the various planes (left side of the entered layers) can be chosen at which the temperature distribution as function of time is depicted.
The last control button at the right bottom side of the screen pictures all the lines together; see picture beneath:

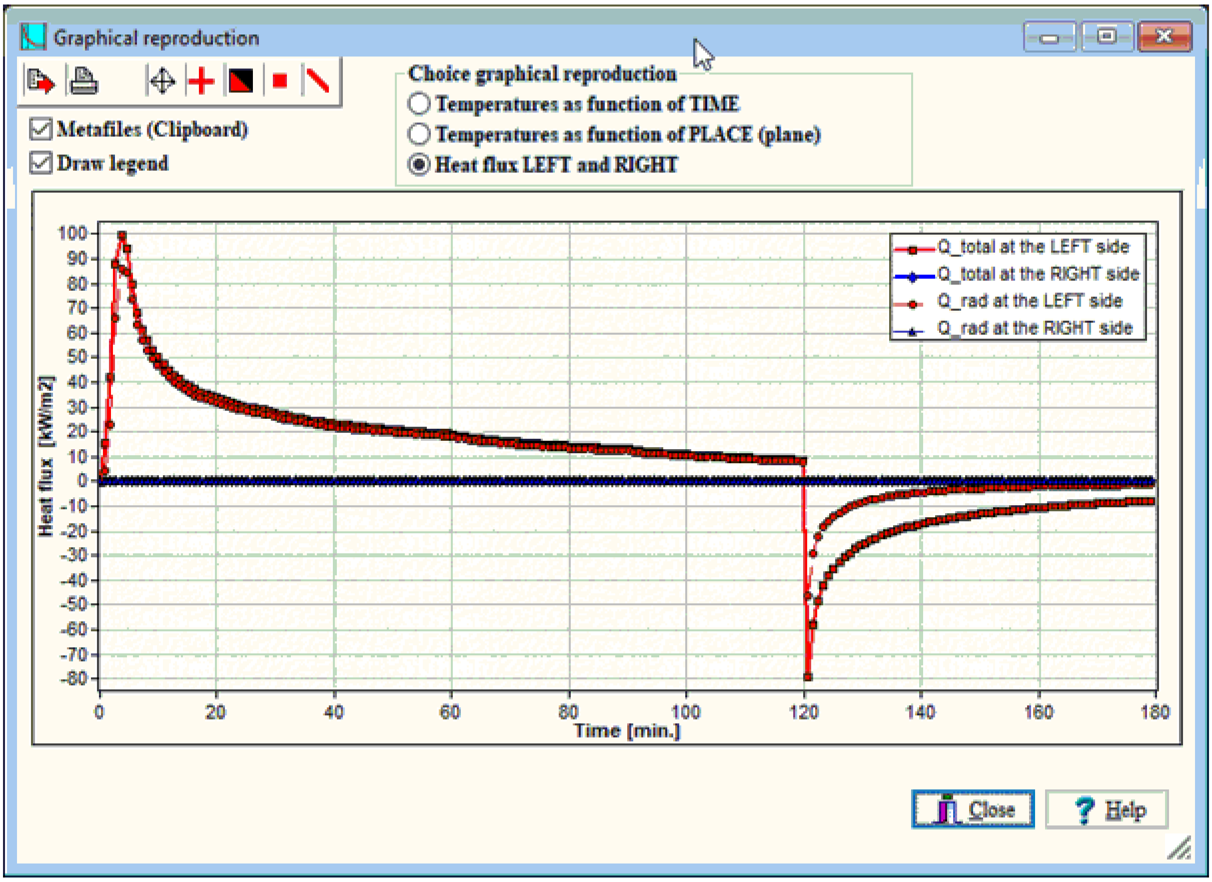


Temperature distribution as function of the time at several places

ad. 3.: See examples beneath:

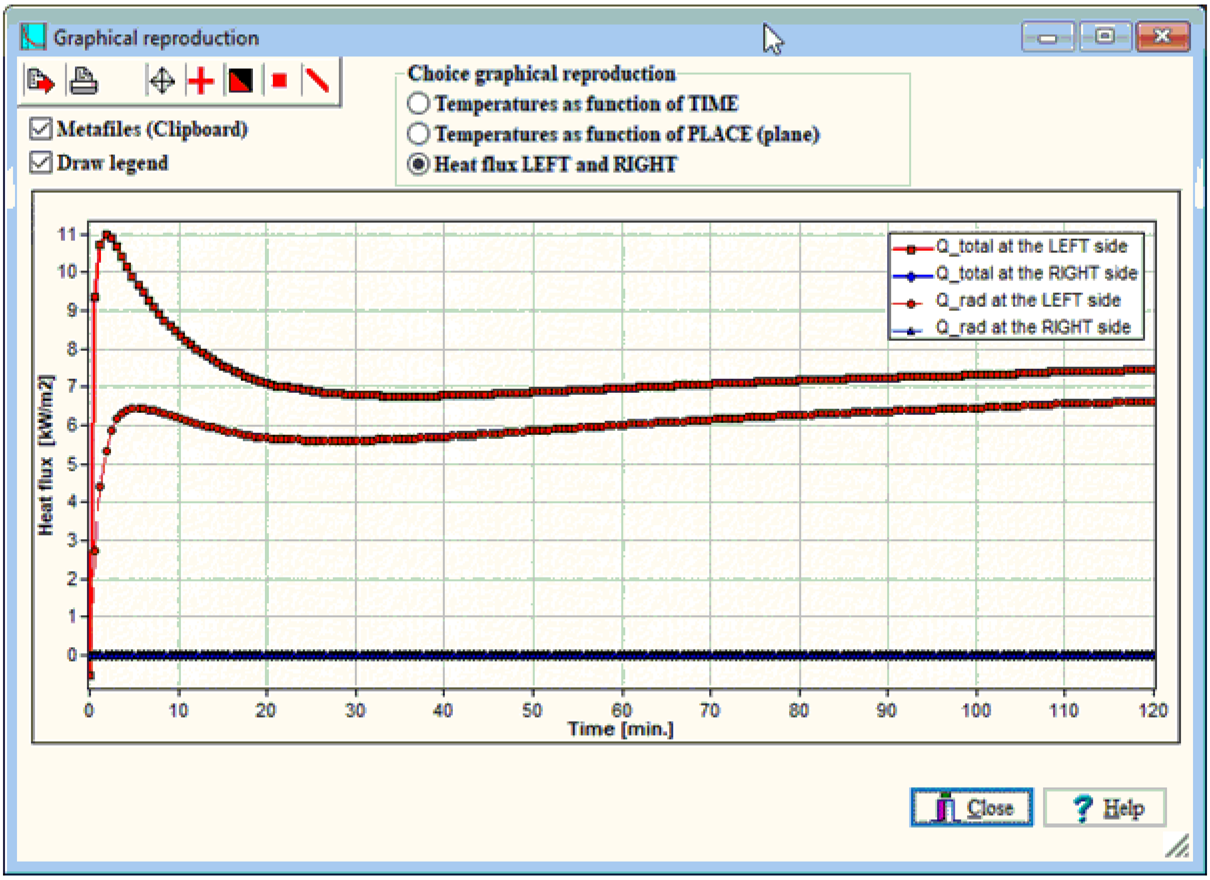


RWS-fire curve; fire board at the left side: Heat flux at the surface at the LEFT and RIGHT side as function of time
(duration fire curve is 120 min. → till 120 min. heat in-flux; > 120 min. heat out-flux)

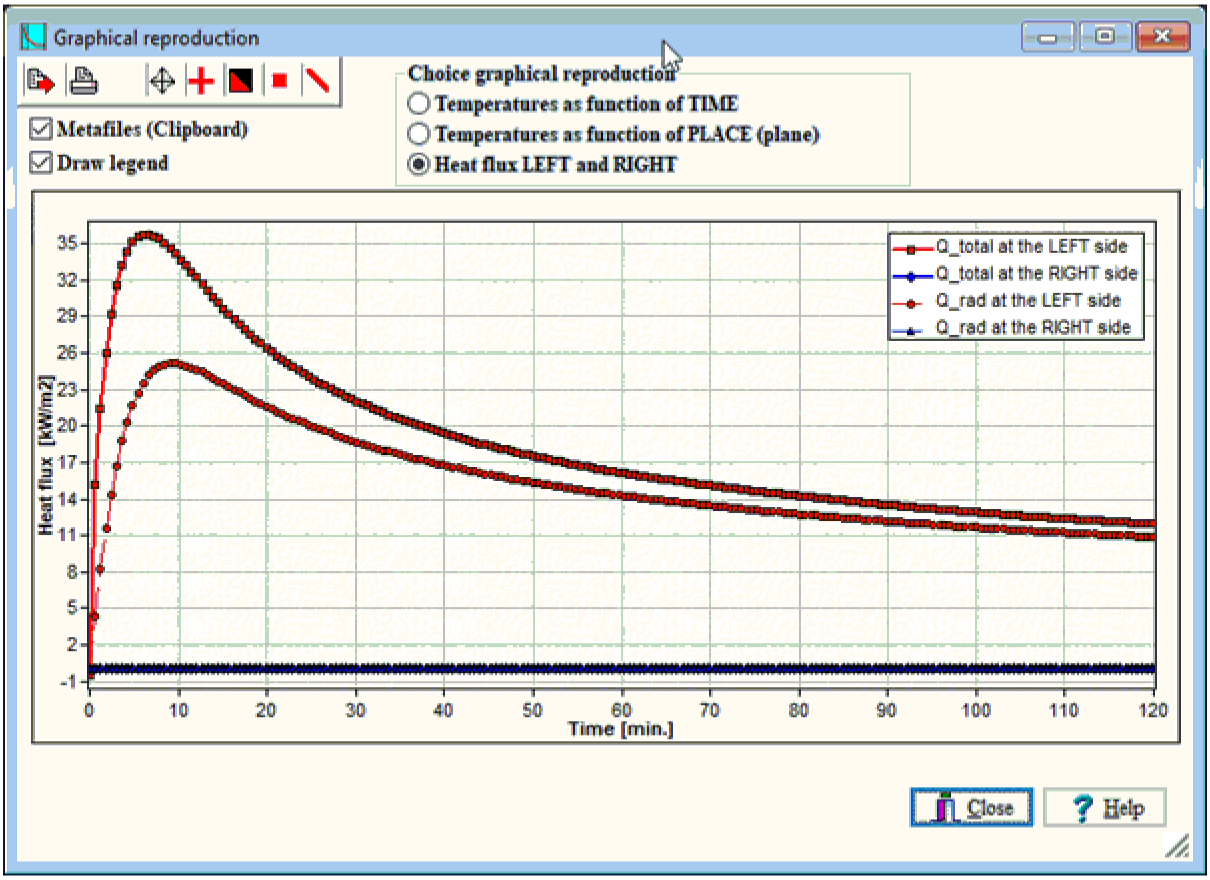


*RWS-fire curve;**NO** fire board at the left side: Heat flux at the surface at the LEFT and RIGHT side as*

function of time
(duration fire curve is 120 min. → till 120 min. heat in-flux; > 120 min. heat out-flux)



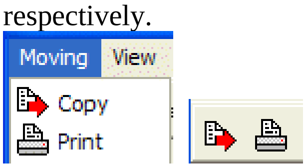
Standard ISO-fire curve; fire board at the left side: Heat flux at the surface at the LEFT and RIGHT side as function of time



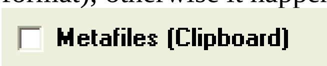
Standard ISO-fire curve; ***NO*** *fire board at the left side: Heat flux at the surface at the LEFT and RIGHT side as function of time*

To clipboard or printer

With the aid of the menu at the left side or de speed buttons the picture can be copied or printed respectively.

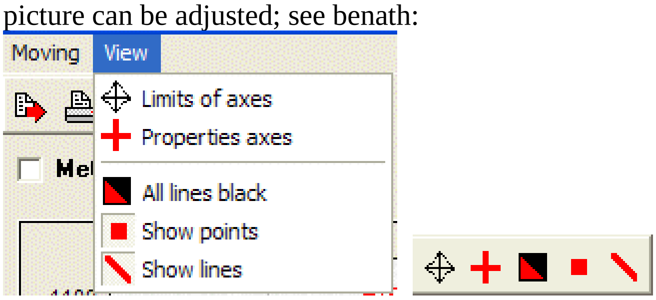


When the box beneath is checked the picture will be copied to the clipboard in vector format (Metafile format); otherwise it happens in bitmap format.

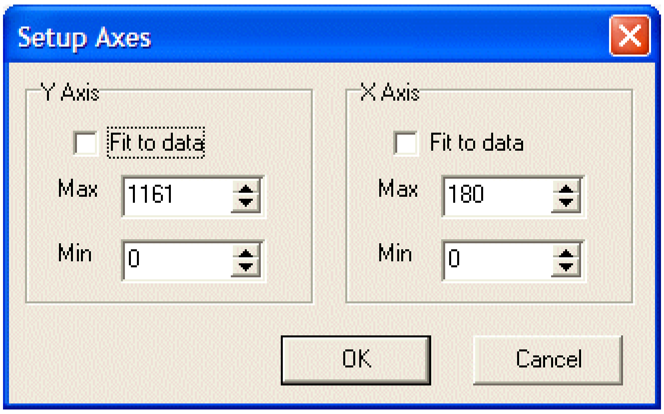


Various setup possibilities

With the aid of the menu or speed buttons a number of items regarding the format and appearance of the picture can be adjusted; see benath:

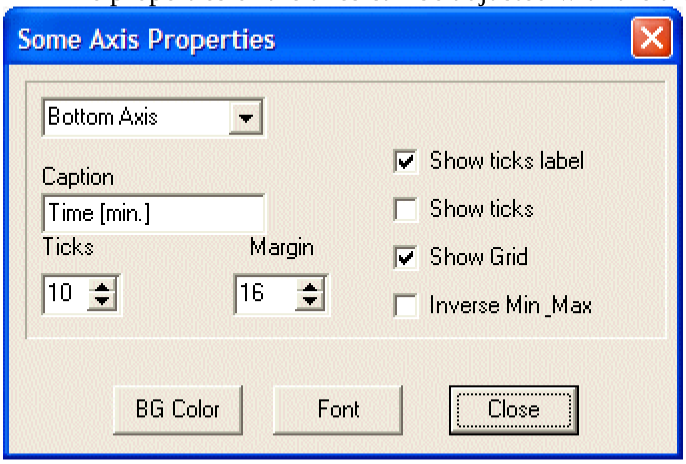


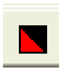
 The limits of the axes can be adjusted with the aid of the window below:

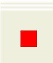


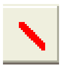
Next to the adjustment of the size of the picture in the window above can be handled as follows:
'Zooming in with pressed "Shift" key and mouse; "Shift" key + mouse click makes zooming undone'

 The properties of the axes can be adjusted with the aid of the window below:



 With this option all lines can be shown in the colour black.

 With this option the marker points can be made visible or invisible

 With this option all line pieces can be made visible or invisible.

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Options

Taal NEDERLANDS

Taal NEDERLANDS

This program is bilingual
With the aid of this menu option a choice can be made of the used language; English or Dutch.
The choice of language can be changed every moment. The setup affects all elements of the program (including input and output).

The setup for the choice of language is saved; this means that at a restart of the program the previous setup is loaded.

Calculator

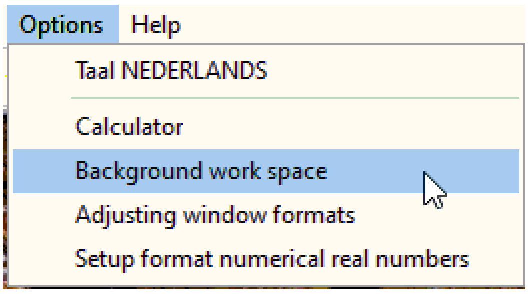
Calculator

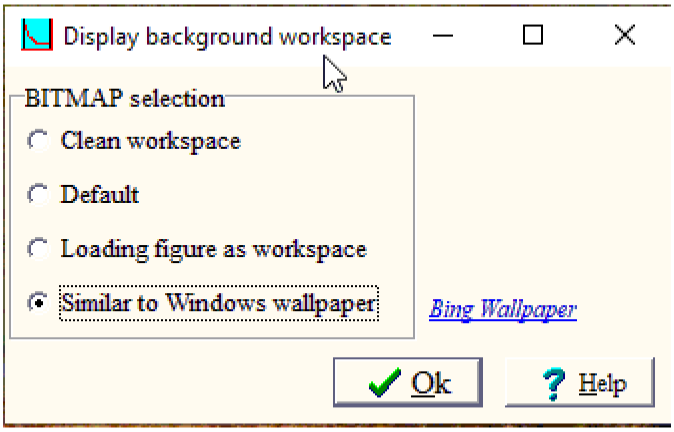
With this menu option the standard Windows based calculator will be opened.
This can be handy for calculations in between.

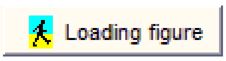
Background work sheet

Background of workplace

With the aid of this option a graphical picture for the work sheet of the program can be set up.





- *Clean workplace*
The background of the workplace is a dull grey colour
- *Default*
Standard a painting from the famous Dutch painter Rembrandt van Rijn (the Night watch) will be shown.
- *Load picture as workplace*
With the aid of the appearing button 

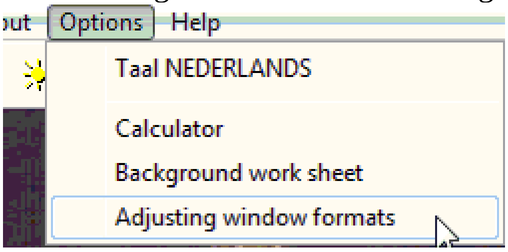
a picture file can be loaded.
- *Equal to Windows wallpaper*
The current Windows background is also used as the background for the program.
The user can make it more dynamic (every day another picture) by installing the '*Bing Wallpaper*'

When the picture for the workplace has been setup once this setup will be saved; when the program restarts the picture on the workplace is the same as was setup the last time.
This window can be shown also by clicking with the right mouse button on the workplace.

Adjusting window formats

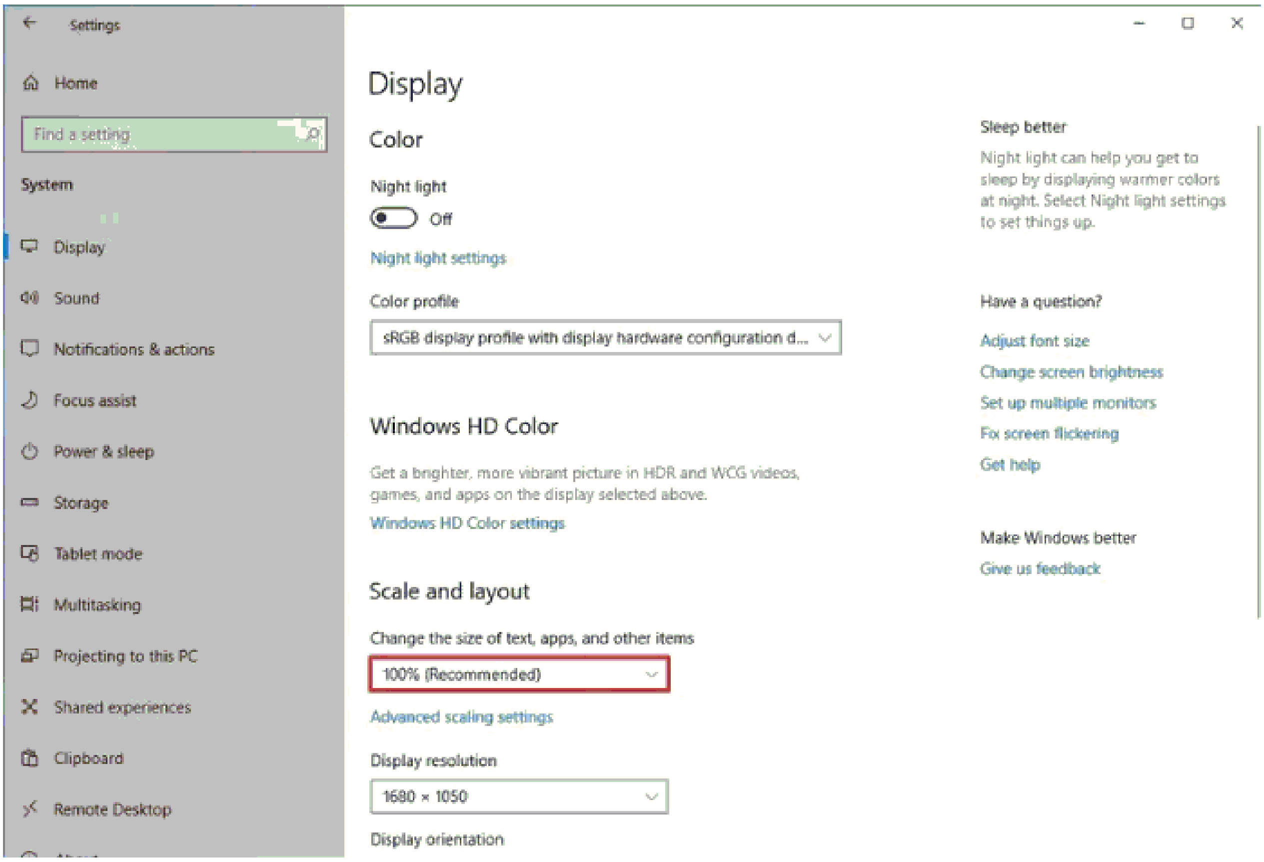
Adjusting format of the windows in relation to the design values

With the aid of this option ‘Adjusting window formats’ the dimensions of the various windows can be changed in relation to the design values; see figure below:

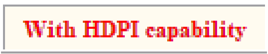


1. Adjustment of dimensions using the Windows 10 window "Settings / Display / Scale and Layout"

This option is available if a version of Windows **after** the Windows "Anniversary Update" edition (number 1607, 2016-08-02) is used.
The program is designed with a screen resolution of 1920 x 1080 dots in mind.
For screens with a much higher resolution screens (such as tablets or 4K monitors) a larger window, compared to the design values, may be desirable for readability.



This window can also be opened from the program by clicking the button



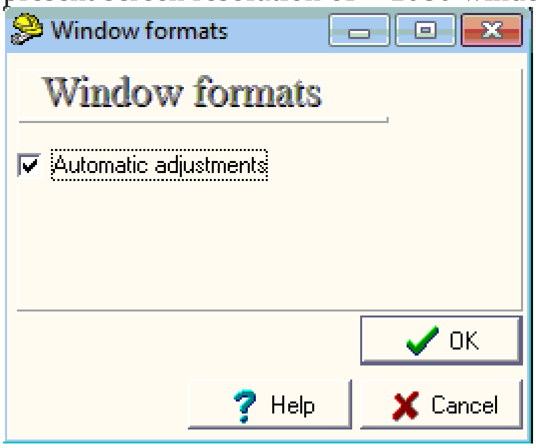
(lower right corner of the main window).
By increasing the "Scale and Layout", readability can be improved on high-resolution displays this way.

2. Built in adjustment of the dimensions of the various windows

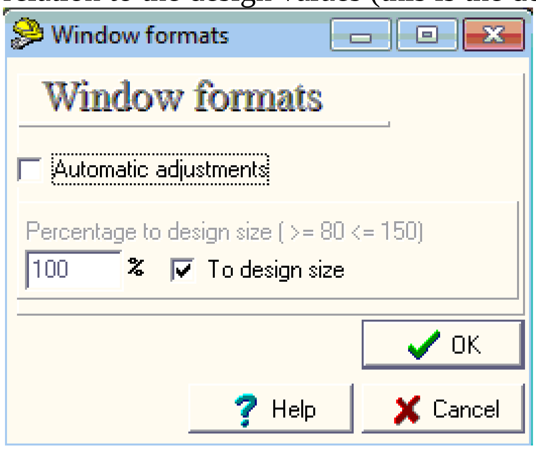
This option is only available if a version of Windows **before** the Windows "Anniversary Update" edition (number 1607, 2016-08-02) is being used.
This is because a better scaling to higher screen resolutions is present in Windows after that date (e.g. 4K)

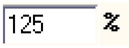
This option only works for those windows which have a **fixed format**.
The option does **not** apply to windows where the dimensions can be changed by the user of the program (like windows serving graphics).
The program is designed with a screen resolution of 1920 x 1080 dots.
For screens with a much higher resolution and/or on smaller screens (such as tablets) a larger window, compared to the design values, may be desirable for readability.
For screens with a lower screen resolution it can be desirable to reduce the size of the windows somewhat, because they otherwise will poorly fit on the screen.
However, this decrease is soon faced with limitations, because there should be enough space to provide a place for the various visual elements onto the windows.

If the checkbox ☑ Automatic adjustments is checked all the windows will scale in relation to the available number of dots into the vertical direction of the screen.
As a reference a value of 1080 is used.
With a present vertical screen resolution of < 1080 windows are **decreased** proportionally, with a present screen resolution of > 1080 windows are **increased** proportionally.

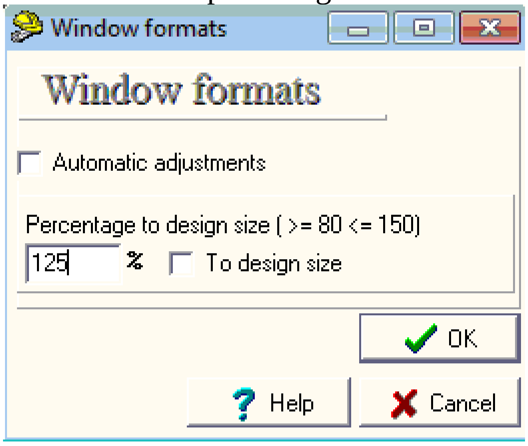


If the checkbox ☑ To design size is checked all the dimensions of the windows will **not** change in relation to the design values (this is the default setup).

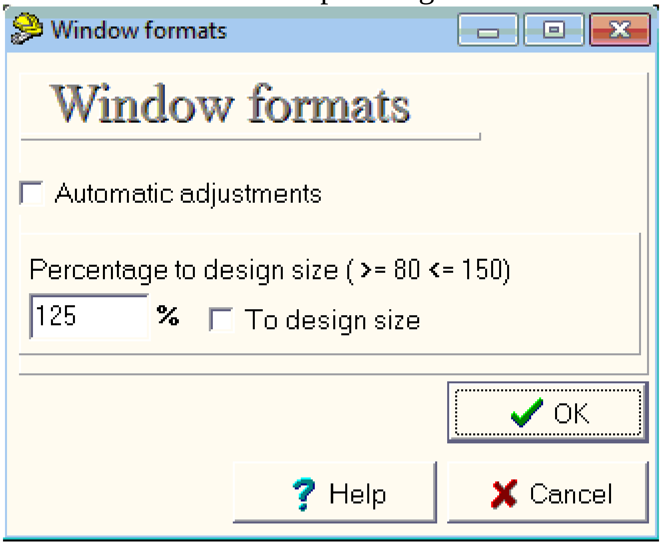


At the box 

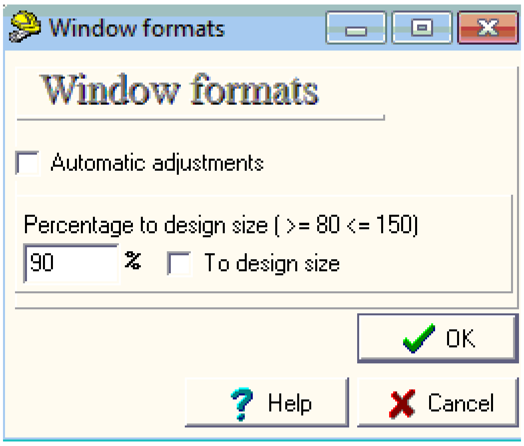
the percentage in relation to the design dimensions can be entered
The size of this percentage has to be >= 80 en <= 150.



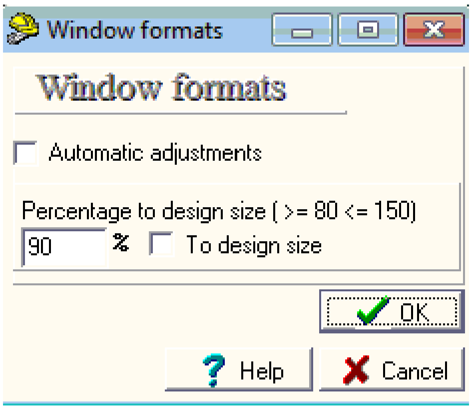
If the window above is opened again the same window appears at a somewhat larger format:



The sizes of the fonts are scaled along as well as possible



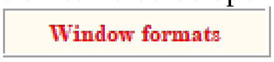
If the window above is opened again the same window appears at a somewhat smaller format:



The sizes of the fonts are scaled along as well as possible

Be aware of the fact that certain controls are not resizable, nor are they resolution independent. Instead they are controlled directly by windows. These controls are: The form's title bar, the font of menus, the small dimension of the scrollbar, the square shape of the checkbox, the circular shape of the radio button, the image of the bit button and the image of the speed button.

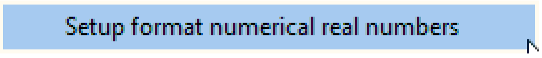
The settings are saved, so that the previously selected settings are used automatically when you restart the program.

This option can also be opened from the program by clicking the button 

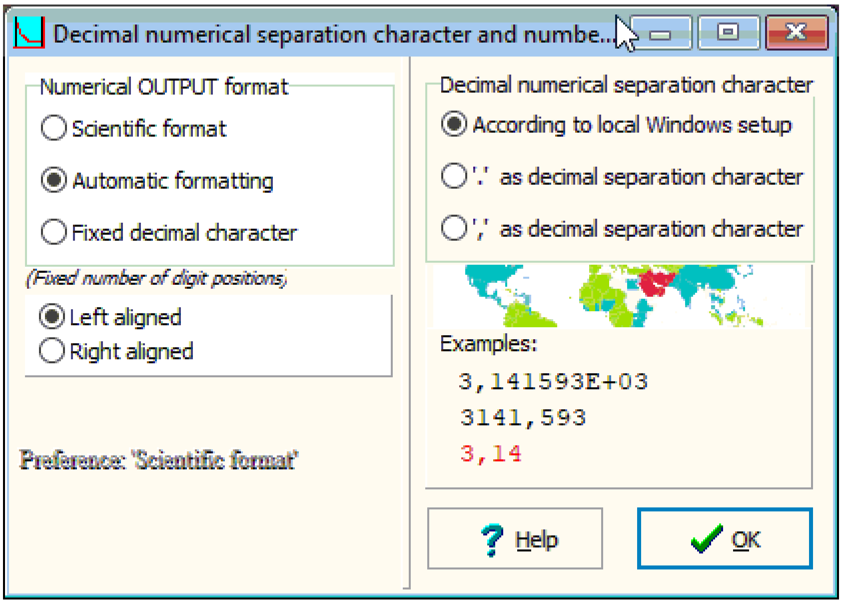
(lower right corner of the main window).

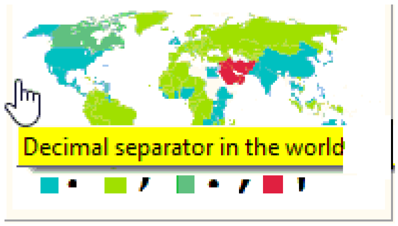
Setup format numerical real numbers

Setup format numerical real numbers

With the aid of this main menu option 

the numerical output format of real numbers can be set-up for the 'Numerical OUTPUT format'.





The character to be used as decimal separator for real numbers can be chosen; i.e. the '**.**' or the '**,**'
By default, the decimal separator is used associated with the local Windows Setup. However, this can be changed (the settings are saved).
For the output of data a choice can be made between the "Scientific format", "Fixed decimal format" and "Automatic formatting".

"Fixed decimal format"	**"Scientific format"**	**"Automatic formatting"**
123.122333	-1.2312E+02	3.14E003
0.00000037	3.7000E-07	3.14

The advantage of the "scientific format" is that both very large numbers and very small numbers do always fit in the reserved space; hence this **"scientific format"** for the viewing of data is the **preferred format**.
When using the "Fixed decimal format" too small numbers are cut off, which can cause precision to be lost. If this is the case then apply one of the 2 other formats.

For the "Automatic formatting" the following rules do apply:
The value is converted to the shortest possible decimal string using fixed or scientific format. The number of significant digits in the resulting string is given by the precision specifier in the format string. Trailing zeros are removed from the resulting string, and a decimal sign appears only if necessary. The resulting string uses the fixed-point format if the number of digits to the left of the decimal sign in the value is less than or equal to the specified precision, and if the value is greater than or equal to 0.00001. Otherwise the resulting string uses scientific format.

For the choice for "Fixed decimal format" or "Automatic formatting" the depiction of a number can be left or right aligned; see example below ("Automatic formatting"):

```
Layer   Temp. Heat conductioncoef.    Temp.   Specific heat
        [°C]        [W/m°C]           [°C]         [J/kg°C]
|----|------|--------------------||-------|-----------------|
  1        20,00          0,169          20,00       966,000
          100,00          0,175          99,00       966,000
          250,00          0,183          99,50     13000,000
          500,00          0,203         100,50     13000,000
          750,00          0,261         101,00       966,000
         1000,00          0,400        1500,00       966,000
         1250,00          0,674       --            --
         1500,00          1,145       --            --
```

```
Layer   Temp. Heat conductioncoef.    Temp.   Specific heat
        [°C]        [W/m°C]           [°C]         [J/kg°C]
|----|------|--------------------||-------|-----------------|
  1     20,00      0,169              20,00     966,000
        100,00     0,175              99,00     966,000
        250,00     0,183              99,50     13000,000
        500,00     0,203              100,50    13000,000
        750,00     0,261              101,00    966,000
        1000,00    0,400              1500,00   966,000
        1250,00    0,674              --            --
        1500,00    1,145              --            --
```

Right aligned *Left aligned*

Input of numerical data

When entering data, however, at the opening of each window, the numerical data is displayed with the chosen format (“Scientific format”, “Fixed decimal format” or “Automatic formatting”).
For the input of the data in such an entry window every format is allowed however; see the example below:

No.	Temperature [°C]	Heat conduction coeff.
1	20	0,169
2	100	0,175
3	250	0,183
4	500	2,03E-1
5	750	0,261
6	1E003	4E-1
7	1,25E003	0,674
8	1,5E003	1,15

Output of numerical data

Example of ‘Scientific format’:

Layer	Temp. [°C]	Heat conductioncoef. [W/m°C]	Temp. [°C]	Specific heat [J/kg°C]
1	2.00E+1	1.6900E-01	2.00E+1	9.6600E+02
	1.00E+2	1.7500E-01	9.90E+1	9.6600E+02
	2.50E+2	1.8300E-01	9.95E+1	1.3000E+04
	5.00E+2	2.0300E-01	1.01E+2	1.3000E+04
	7.50E+2	2.6100E-01	1.01E+2	9.6600E+02
	1.00E+3	4.0000E-01	1.50E+3	9.6600E+02
	1.25E+3	6.7400E-01	--	--
	1.50E+3	1.1500E+00	--	--

Example of 'Automatic format':

Layer	Temp. [°C]	Heat conductioncoef. [W/m°C]	Temp. [°C]	Specific heat [J/kg°C]
1	20	0.169	20	966
	1E002	0.175	99	966
	2.5E002	0.183	1E002	1.3E004
	5E002	0.203	1E002	1.3E004
	7.5E002	0.261	1E002	966
	1E003	0.4	1.5E003	966
	1.3E003	0.674	--	--
	1.5E003	1.15	--	--

Example of 'Fixed-point format':

Layer	Temp. [°C]	Heat conductioncoef. [W/m°C]	Temp. [°C]	Specific heat [J/kg°C]
1	20.00	0.169	20.00	966.000
	100.00	0.175	99.00	966.000
	250.00	0.183	99.50	13000.000
	500.00	0.203	101.00	13000.000
	750.00	0.261	101.00	966.000
	1000.00	0.400	1500.00	966.000
	1250.00	0.674	--	--
	1500.00	1.150	--	--

The choice been made will be saved, so that at a new start of the program the setup will be maintained.

Help

Helpindex

Short description of the PCTempFlow program:

Purpose of the program:

This program calculates the **time dependent** temperature distribution in a layered structure as a function of time.
The considered geometry is one-dimensional.
The program is primarily written in view of the calculation of fires, but is also suitable for use at much lower temperatures.

At the left side of the first layer at the right side of the last layer a prescribed heat source is present during a certain time.
There are THREE possibilities present for the input of the conditions:

1. Input of the air temperature [°C]
2. Input of the incoming radiation [kW/m^2]
3. Combination of point 1. and 2.

At point 1. next to air temperature the heat transition coefficient has to be given [W/m^2 °C]
For point 2. the first layer is radiating somewhat backwards as a consequence of the raise in temperature and therefore lowering the temperature somewhat (especially at higher surface temperatures).
For option 3. the amount of energy is put into the structure by convection as well as radiation.

For the input of air temperatures and radiation at both sides various more or less complex options are available.

In the various layers heat transport takes place by convection only.
It is possible, if water is present, to limit the temperatures to a maximum of 100 degrees Celsius.
In a possible cavity heat transport is only calculated by means of radiation.

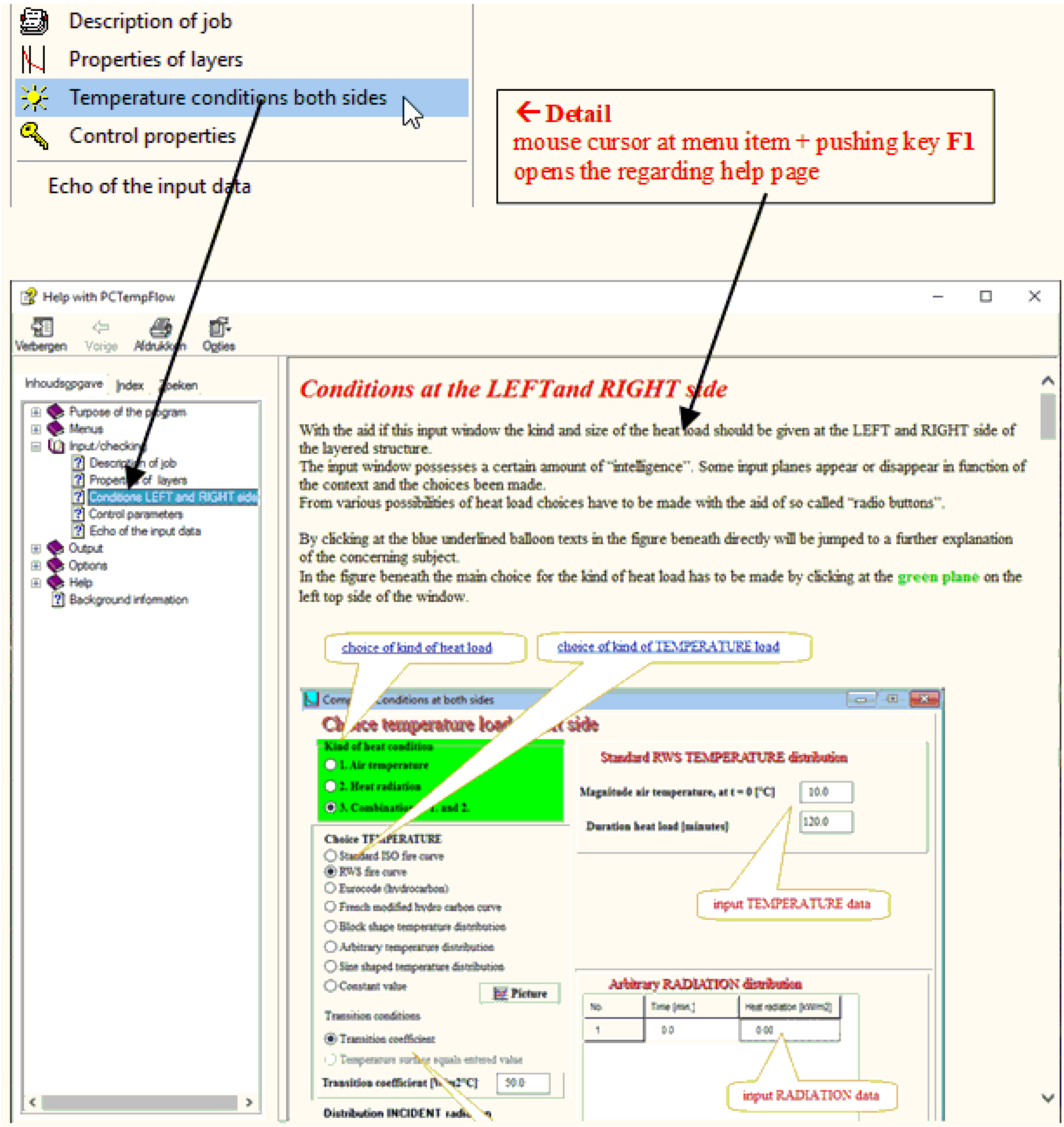
The output of the calculations results is possible in numerical as well as graphical form.

Limitation of the scope

For the material concrete any spalling in the event of a fire is not taken into account.
The process of concrete spalling in the event of a fire is a very complex mechanism for which no reliable calculation models are (yet) available.

Attention !!

Practically everywhere in the program help can be acquired by touching the function key **F1**.
Let for instance the mouse rest at a certain menu option and push at the same time de key F1; the context sensitive help will then appear (see also the example beneath).

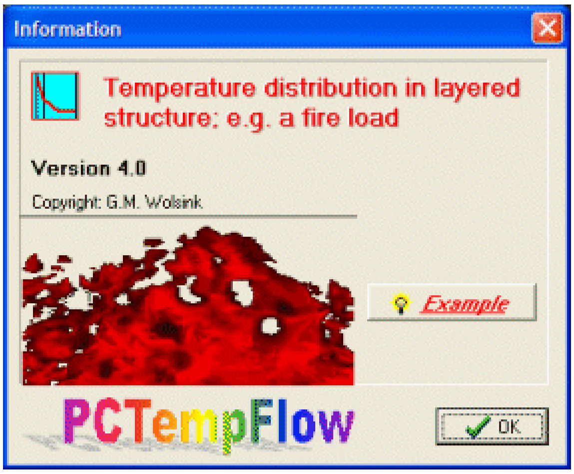


At a number of windows also help can be acquired by pushing the special help button (pressing the **F1** key works also at these places).

About..

About…

This little window opens at the start of the program; it’s also accessible via the Help main menu option.



Via the button 

an example data file will be loaded automatically.
For new users with the aid of this example a swift and easy way is available to make a reconnaissance about the possibilities of the program.

Limitations

Limitations

At this window a number of maximum values is shown; these values may not be exceeded at the input of data.
It concerns the following properties:

- Number of lines for descriptive text per layer; see also at Description of job
- Number of layers for the structure; see also at Properties of the layers
- Number of time dependent properties; see also at Properties of the layers
- Number of points for arbitrary load at the LEFT side; see also at Conditions LEFT side
- Total duration of the fire in minutes; see also at Control parameters
- Number of allowable time steps for the calculation; see also at Control parameters
- Number of allowable time steps for the output (numerical and graphical) ; see also at Control parameters

The program checks whether of not a maximum is exceeded and warns for it.

E-mail

E-mail

With the aid of this option the at the computer installed E-mail program will be started (for instance from Microsoft or Thunderbird), with the E-mail address of the author of this program already filled in (wolsink@ziggo.nl).
The purpose of this option is to exchange experiences about the program by the user at a very easy way.

This option functions of course only when the regarding software is installed at the concerning computer and the entrance to the Internet is available.

See further also: Homepage

Homepage

Homepage

With the aid of this menu the default Internet browser will be started and made contact with the home page of the author (https://gerritwolsink.nl/) of this computer program.
It is recommended to visit this home page periodically and to check if a new version of the program is available; this one can be down loaded then.

You can use as well the option: Check for newer version

Check for newer version

Check for a newer version

With the aid of this menu it can be checked whether or not a newer version of the software is available from the Internet. This happens without opening the Internet browser.
In order to use this option you need of course an Internet connection.

After the check via the Internet you are informed whether or not a newer version can be download from the Internet.

See further also: E-mail and Homepage.

Background information

Backgrounds to the program

The following aspects will be treated here:

- Heat transport by conduction
- Border conditions
- Numerical schematisation
- Equivalent temperature

Heat transport by conduction

Starting point is an one dimensional temperature flow described by the partial differential equation of FOURIER.

The PDE of FOURIER for an one dimensional time dependent heat flow:

$$\rho.c(T)\frac{\partial T}{\partial t} = \frac{\partial \lambda(T)}{\partial x}.\frac{\partial T}{\partial x} + \lambda(T).\frac{\partial^2 T}{\partial x^2} \quad \textbf{(1)}$$

where:

ρ = specific mass
$c(T)$ = temperature dependent specific heat
$\lambda(T)$ = temperature dependent heat conduction coefficient
T = temperature
t = time
x = coordinate

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Border conditions

1.1. Prescribed temperature

$$T_s = T_{air} \quad \textbf{(2)}$$

1.2. Via conduction

The heat flux at the border via **conduction** can be described with the formula beneath:

$$q = \alpha.(T_s - T_{air}) \quad \textbf{(3)}$$

where:

q = heat flux
α = heat transition coefficient
$T_{s.}$ = temperature at the surface
T_{air} = air/gas temperature

1.3. Via conduction + radiation

Due to the presence of a heat transition coefficient, a temperature difference arises between the temperature of the soot and the temperature at the surface.
As a result, there is also a heat flow due to radiation in accordance with Stefan-Boltzmann's law (temperature in [ºK])
The total heat flow becomes:

$$q = \alpha.(T_s - T_f) + \sigma.\varepsilon_{s}.(T_s^4 - T_f^4) \quad \textbf{(4)}$$

where:

q = heat flux
α = heat transition coefficient of the surface
σ = Stefan-Boltzmann constant = 5.67051E-8 [W/(m^2.°K)]
ε_S = emission coefficient ≅ absorption coefficient of the surface (according to Kirchhoff's identity)

The emissivity coefficient – ε_S - indicates the radiation of heat from a **'grey body'** according the Stefan-Boltzmann Law**,** compared with the radiation of heat from an ideal **'black body'** with the emissivity coefficient ε_S = 1.

In the program the default value ε_S = 0.7 (in agreement with EN 1992-1-2 art. 2.2.(2) for concrete surfaces)

$T_{S.}$ = temperature at the surface
T_f = effective radiation temperature of the fire [ºK]

1.4. Via radiation transfer in a cavity

he **radiation transport** at a cavity follows the law of Stefan-Boltzmann:

$$q = \sigma.\varepsilon.\left(T_i^4 - T_j^4\right) \quad \textbf{(5)}$$

where:
q = heat flux
σ = Stefan-Boltzmann constant = 5.67051E-8 [W/(m^2.°C)]
ε = emission coefficient ≅ absorption coefficient
T_i, T_j = temperature, at place i and j

2. Only incoming radiation

The heat flux at the border via **radiation** can be described with the formula beneath:

$$q = -\varepsilon.q_{in} \quad \textbf{(6)}$$

where:
q = heat flux
ε = emission coefficient ≅ absorption coefficient
q_{in} = incoming heat radiation

3. Incoming radiation + via conduction

$$q = -\varepsilon.q_{in} + \alpha.(T_s - T_0) \quad \textbf{(7)}$$

where:
T_0 = Temperature to which it is beamed back

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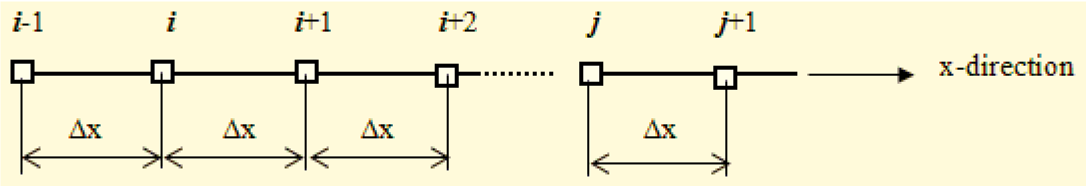
Numerical schematisation

Implicit method

An important advantage of this implicit calculation method, contrary to the explicit method, that it's unconditionally stable.
The most important disadvantage of implicit calculation methods is the more difficult implementation of them.

Differential equation (1)

For the solving of the transient heat equation and the incorporation of border- and transition conditions use is made of the method of finite differences.
For the purpose of this calculation method a number of nodes have to be generated along the thickness; see below:



The term $\frac{\partial T}{\partial x}$ from formulae **(1),** at the place of node ***i,*** can be determined with 2[e] order accuracy as follows:

$$\left(\frac{\delta T}{\delta x}\right) = \frac{T_{i+1}^{n+1} - T_{i-1}^{n+1}}{2.\Delta x} + O(\Delta x^2) \qquad \textbf{(8)}$$

in which:

T_i^{n+1} = temperature at place ***i*** and time step ***n+1***
Δx = place distance between nodes
$O(\Delta x^2)$ = order of the truncation error

The term $\frac{\partial^2 T}{\partial x^2}$ from formulae **(1),** at the place of node ***i,*** can be determined with 2[e] order accuracy as follows:

$$\left(\frac{\delta^2 T}{\delta x^2}\right) = \frac{T_{i+1}^{n+1} - 2T_i^{n+1} + T_{i-1}^{n+1}}{\Delta x^2} + O(\Delta x^2) \qquad \textbf{(9)}$$

For the terms $\frac{\delta T}{\delta t}$ and $\frac{\partial \lambda(T)}{\partial x}$ in formulae **(1)** an analogous approach holds:

$$\left(\frac{\delta T}{\delta t}\right) = \frac{T_i^{n+1} - T_i^n}{\Delta t} + O(\Delta t) \qquad \textbf{(10)}$$

$$\left(\frac{\delta \lambda(T)}{\delta x}\right) = \frac{\lambda_{i+1}^n - \lambda_{i-1}^n}{2.\Delta x} + O(\Delta x^2) \qquad \textbf{(11)}$$

Equation **(1)** can be rewritten thereby as follows:

$$\rho.c_i^n \left(\frac{T_i^{n+1} - T_i^n}{\Delta t}\right) = \left(\frac{\lambda_{i+1}^n - \lambda_{i-1}^n}{2.\Delta x}\right)\left(\frac{T_{i+1}^{n+1} - T_{i-1}^{n+1}}{2.\Delta x}\right) + \lambda_i^n \left(\frac{T_{i+1}^{n+1} - 2T_i^{n+1} + T_{i-1}^{n+1}}{\Delta x^2}\right) \qquad \textbf{(12)}$$

ofwel:

$$-\boldsymbol{T_{i-1}^{n+1}} C1.(C2 - C3) + \boldsymbol{T_i^{n+1}}(1 + 2.C1.C2) - \boldsymbol{T_{i+1}^{n+1}}.C1.(C2 + C3) = T_i^n$$

with

$$C1 = \frac{\Delta t}{\rho.c_i^n}$$
$$C2 = \frac{\lambda_i^n}{\Delta x^2}$$
$$C3 = \frac{\lambda_{i+1}^n - \lambda_{i-1}^n}{4.\Delta x^2}$$

Note that with the aid of (12) an asymmetric tri-diagonal matrix is obtained (unless C3=0).

Border conditions; formulae (3) -- heat-influx via conduction

Left side:

At the left side applies: $q = \alpha_l.\left(T_{air,l}^{n+1} - T_1^{n+1}\right)$ **(13)**

At the side of the structure applies: $q = -\frac{\lambda_1^n}{2.\Delta x}.\left(T_2^{n+1} - T_0^{n+1}\right)$ **(14)**

in which:

i=1 is the index of the node placed at the left edge

Equating of **(13)** and **(14)** gives: $T_0^{n+1} = T_2^{n+1} + \frac{2.\alpha_l.\Delta x}{\lambda_1^n}.\left(T_{air,l}^{n+1} - T_1^{n+1}\right)$ **(15)**

Formulae **(15)** is entered next into formulae **(12)**; in simplified version:

$T_1^{n+1} - \frac{\lambda_1^n.\Delta t}{\rho.c_1^n\Delta x^2}.\left(T_2^{n+1} - 2T_1^{n+1} + T_0^{n+1}\right) = T_1^n$ **(12_a)**

remark:

The simplified version of formulae (12) is used because otherwise the term λ_0^n is part of the equation (property at virtual point).

$\boldsymbol{T_1^{n+1}}(1 + 2.C4 + C4.C5) - \boldsymbol{T_2^{n+1}}.2.C4 = T_1^n + C4.C5.T_{air,l}^{n+1}$ **(16)**

with

$C4 = \frac{\lambda_1^n.\Delta t}{\rho.c_1^n\Delta x^2}$

$C5 = \frac{2.\alpha_l.\Delta x}{\lambda_1^n}$

Rigth side:

At the right side applies: $q = \alpha_r.\left(T_m^{n+1} - T_{air,r}^{n+1}\right)$ **(17)**

At the side of the structure applies: $q = -\frac{\lambda_m^n}{2.\Delta x}.\left(T_{m+1}^{n+1} - T_{m-1}^{n+1}\right)$ **(18)**

in which:

i=m is the index of the node placed at the right edge

Equating of **(17)** and **(18)** gives: $T_{m+1}^{n+1} = T_{m-1}^{n+1} - \frac{2.\alpha_r.\Delta x}{\lambda_m^n}.\left(T_m^{n+1} - T_{air,r}^{n+1}\right)$ **(19)**

Formulae **(19)** is entered next into formulae **(12);** in simplified version

$T_m^{n+1} - \frac{\lambda_m^n.\Delta t}{\rho.c_m^n\Delta x^2}\left(T_{m+1}^{n+1} - 2T_m^{n+1} + T_{m-1}^{n+1}\right) = T_m^n$ **(12_a)**

$-\boldsymbol{T_{m-1}^{n+1}}.2.C6 + \boldsymbol{T_m^{n+1}}(1 + 2.C6 + C6.C7) = T_m^n + C6.C7.T_{air,r}^{n+1}$ **(20)**

with

$C6 = \frac{\lambda_m^n.\Delta t}{\rho.c_m^n.\Delta x^2}$

$C7 = \frac{2.\alpha_r.\Delta x}{\lambda_m^n}$

Border conditions; formulae (4) – heat influx via **conduction + radiation**

Left side:

At the left side applies for node 1:

$q = \alpha_l.\left(T_{air,1}^{n+1} - T_1^{n+1}\right) + \varepsilon.\sigma.\left(T_{air,1}^{4,n+1} - T_1^{4,n+1}\right) = \alpha_l.\left(T_{air,1}^{n+1} - T_1^{n+1}\right) + q_{rad,l}^{n+1}$ **(21)**

At the side of the structure applies: $q = -\frac{\lambda_1^n}{2.\Delta x}.\left(T_2^{n+1} - T_0^{n+1}\right)$ **(22)**

in which:

i=1 is the index of the node placed at the left edge

Equating of **(21)** and **(22)** gives:

$$T_0^{n+1} = T_2^{n+1} + \frac{2.\Delta x}{\lambda_1^n}.\left\{\alpha_l.\left(T_{air,1}^{n+1} - T_1^{n+1}\right) + q_{rad,l}^{n+1}\right\} \qquad \textbf{(23)}$$

Formulae **(23)** is entered next into formulae **(12);** in simplified version:

$$T_1^{n+1} - \frac{\lambda_1^n.\Delta t}{\rho.c_1^n\Delta x^2}.\left(T_2^{n+1} - 2T_1^{n+1} + T_0^{n+1}\right) = T_1^n \qquad \textbf{(12\_a)}$$

$$T_1^{n+1}.(1 + 2.C4 + C4.C5) - T_2^{n+1}.2.C4 = T_1^n + C4.C5.\left(T_{air,1}^{n+1} + \frac{q_{rad,l}^{n+1}}{\lambda_1^n}\right) \qquad \textbf{(24)}$$

with

$$C4 = \frac{\lambda_1^n.\Delta t}{\rho.c_1^n\Delta x^2}$$
$$C5 = \frac{2.\alpha_l.\Delta x}{\lambda_1^n}$$

Rigth side:
At the right side for node m:

$$q = \alpha_r.\left(T_m^{n+1} - T_{air,m}^{n+1}\right) + \varepsilon.\sigma.\left(T_m^{4,n+1} - T_{air,1}^{4,n+1}\right) = \alpha_r.\left(T_m^{n+1} - T_{air,r}^{n+1}\right) + q_{rad.r}^{n+1} \qquad \textbf{(25)}$$

At the side of the structure applies: $q = -\frac{\lambda_m^n}{2.\Delta x}.\left(T_{m+1}^{n+1} - T_{m-1}^{n+1}\right)$ **(26)**
in which:
i=m is the index of the node placed at the right edge

Equating of **(25)** and **(26)** gives:

$$T_{m+1}^{n+1} = T_{m-1}^{n+1} - \frac{2.\Delta x}{\lambda_m^n}.\left\{\alpha_r.\left(T_m^{n+1} - T_{air,r}^{n+1}\right) + q_{rad,m}^{n+1}\right\} \qquad \textbf{(27)}$$

Formulae **(19)** is entered next into formulae **(12_a);** in simplified version:

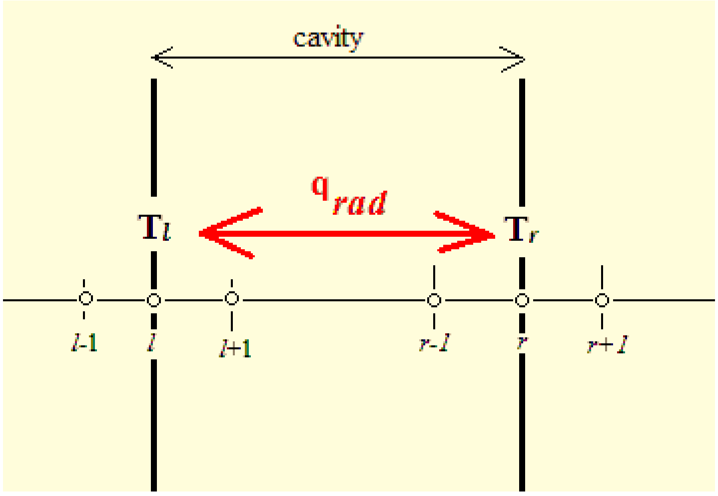
$$T_m^{n+1} - \frac{\lambda_m^n.\Delta t}{\rho.c_m^n\Delta x^2}\left(T_{m+1}^{n+1} - 2T_m^{n+1} + T_{m-1}^{n+1}\right) = T_m^n \qquad \textbf{(12\_a)}$$

$$-T_{m-1}^{n+1}.2.C6 + T_m^{n+1}.(1 + 2.C6 + C6.C7) = T_m^n + C6.C7.\left(T_{air,r}^{n+1} + \frac{q_{rad,r}^{n+1}}{\lambda_m^n}\right) \qquad \textbf{(28)}$$

with

$$C6 = \frac{\lambda_m^n.\Delta t}{\rho.c_m^n.\Delta x^2}$$
$$C7 = \frac{2.\alpha_r.\Delta x}{\lambda_m^n}$$

Border conditions at a cavity (radiative transfer only); formulae (5)



Left side of the cavity:

$$q = -\sigma.\varepsilon.\left(T_r^{n\,4} - T_l^{n\,4}\right) = -q_{rad} \qquad \textbf{(5)}$$

At the left side of the cavity applies $q = -\frac{\lambda_l^n}{2.\Delta x}.\left(T_{l+1}^{n+1} - T_{l-1}^{n+1}\right)$ **(29)**

in which:

i=*l* is the index of the node placed at the left side of the cavity

Equating of **(5)** and **(29)** gives $T_{l+1}^{n+1} = q_{rad}.\frac{2.\Delta x}{\lambda_l^n} + T_{l-1}^{n+1}$ **(30)**

Formulae **(30)** is entered next into formulae **(12)**; in simplified version:

$$T_l^{n+1} - \frac{\lambda_l^n.\Delta t}{\rho.c_l^n.\Delta x^2}.\left(T_{l+1}^{n+1} - 2T_l^{n+1} + T_{l-1}^{n+1}\right) = T_l^n \qquad \textbf{(12\_a)}$$

$$-\boldsymbol{T_{l-1}^{n+1}}.2.C8 + \boldsymbol{T_l^{n+1}}(1 + 2.C8) = T_l^n - C9.q_{rad} \qquad \textbf{(31)}$$

with

$$C8 = \frac{\lambda_l^n.\Delta t}{\varrho.c_l^n.\Delta x^2}$$
$$C9 = \frac{2.\Delta t}{\varrho.c_l^n.\Delta x}$$

Rigth side of the cavity:

At the right side of the cavity applies: q $q = -\frac{\lambda_r^n}{2.\Delta x}.\left(T_{r+1}^{n+1} - T_{r-1}^{n+1}\right)$ **(32)**

in which:

i=*r* is the index of the node placed at the right side of the cavity

Equating of **(5)** and **(32)** gives: $T_{r-1}^{n+1} = q_{rad}.\frac{2.\Delta x}{\lambda_r^n} + T_{r+1}^{n+1}$ **(33)**

Formulae **(33)** is entered next into formulae **(12);** in simplified version:

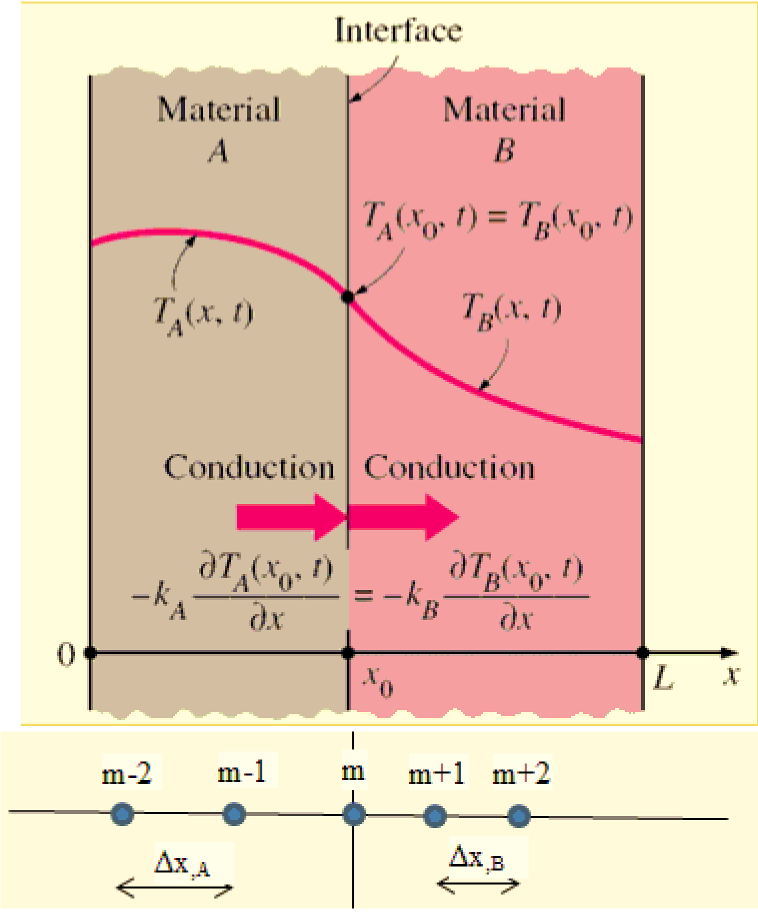
$$T_r^{n+1} - \frac{\lambda_r^n.\Delta t}{\rho.c_r^n.\Delta x^2}.\left(T_{r+1}^{n+1} - 2T_r^{n+1} + T_{r-1}^{n+1}\right) = T_r^n \qquad \textbf{(12\_a)}$$

$$\boldsymbol{T_r^{n+1}}.(1 + 2.C10) - \boldsymbol{T_{r+1}^{n+1}}.2.C10 = T_r^n + C11.q_{rad} \qquad \textbf{(34)}$$

with

$$C10 = \frac{\lambda_r^n.\Delta t}{\varrho.c_r^n.\Delta x^2}$$
$$C11 = \frac{2.\Delta t}{\varrho.c_r^n.\Delta x}$$

Layer transition conditions



$$q = -\lambda_A . \frac{(T_m^{n+1} - T_{m-2}^{n+1})}{2.\Delta x_A} = -\lambda_B . \frac{(T_{m+2}^{n+1} - T_m^{n+1})}{2.\Delta x_B} \qquad \textbf{(35)}$$

with

$$\alpha = \frac{\lambda_A}{2.\,\Delta x_A}$$

$$\beta = \frac{\lambda_B}{2.\,\Delta x_B}$$

follows:

$$T_m^{n+1} = \frac{\alpha.T_{m-2}^{n+1} + \beta.T_{m+2}^{n+1}}{\alpha + \beta} \qquad \textbf{(36)}$$

A similar approach is followed for the other border conditions.

The solution of the system of equations for each time step is done with the **tridiagonal matrix algorithm (TDMA)**, also known as the **Thomas algorithm**.
See for further backgrounds about this method: http://nl.wikipedia.org/wiki/Tridiagonale-matrix-algoritme

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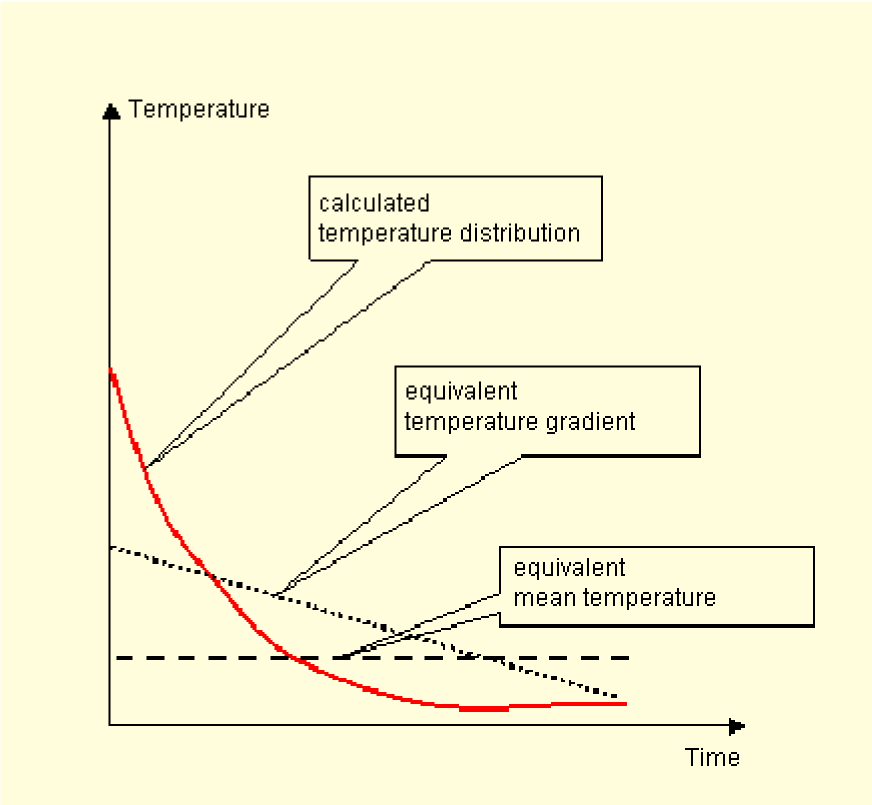
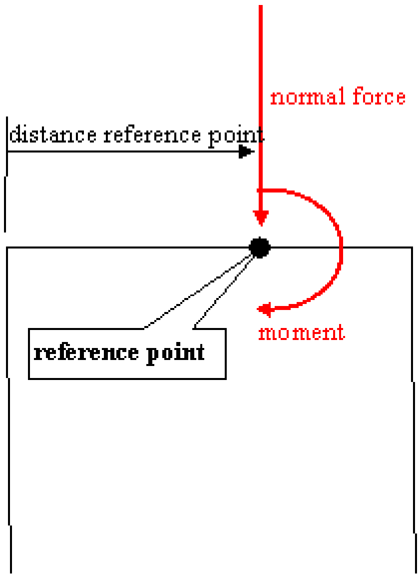
Equivalent temperature

Using the ***equivalent*** mean temperature and gradient as input in a framework program (using the value for the E-modulus at 'normal' temperatures [20°C]) calculates the same force distribution in the frame as the true non-linear temperature distribution at a given time .
The program Framework does support the input and calculation of temperature beam loads for instance.
This should be calculated for the time-step with the maximal equivalent linear temperature distribution to find the maximal effect for the structure of course.

See for illustration purposes the figure below:





Equivalent mean temperature

$$T_{eq,m} = \frac{\sum_{i=1}^{n} E_{i,T_i}.\Delta x_i.C_{i,T_i}.T_i}{\sum_{i=1}^{n} E_{i,T_0}.\Delta x_i.C_{i,T_0}}$$

in which

$T_{eq,m}$ = mean equivalent temperature

$E_{i,Ti}$ = E-modulus in layer i at temperature T_i

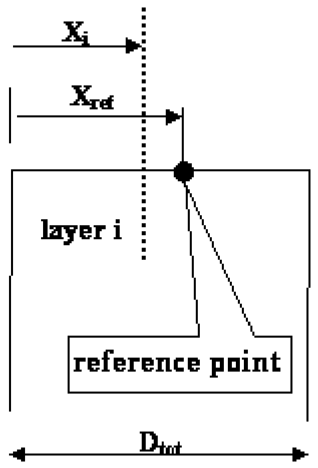
Δx_i = width layer i

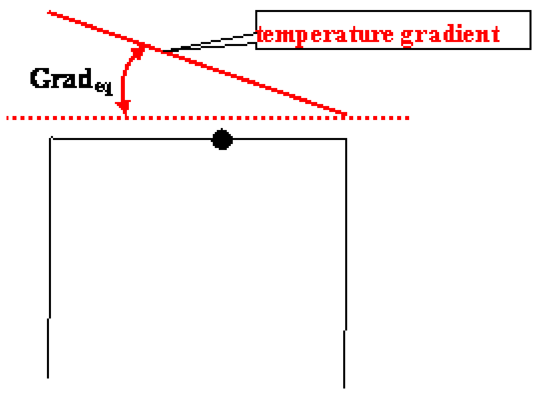
$C_{i,Ti}$ = expansion coefficient in layer i at temperature T_i
T_i = temperature in layer i
$E_{i,T0}$ = E-modulus in layer i at temperature T_0 (temperature at the start of the calculation)
$C_{i,T0}$ = expansion coefficient in layer i at temperature T_0 (temperature at the start of the calculation)

Equivalent temperature gradient

$$Grad_{eq} = \frac{\sum_{i=1}^{n} E_{i,T_i}.\Delta x_i.C_{i,T_i}.T_i.\left(X_i - X_{ref}\right)}{\sum_{i=1}^{n} E_{i,T_0}.\Delta x_i.C_{i,T_0}.\left(X_i - X_{ref}\right).\left(1 - X_i / D_{tot}\right)}$$

in which
$Grad_{eq}$ = equivalent temperature gradient
$E_{i,Ti}$ = E-modulus in layer i at temperature T_i
Δx_i = width layer i
$C_{i,Ti}$ = expansion coefficient in layer i at temperature T_i
T_i = temperature in layer i
X_i = distance of layer i to left side (origin)
X_{ref} = distance reference point to left side (origin)
$E_{i,T0}$ = E-modulus in layer i at temperature T_0 (temperature at the start of the calculation)
$C_{i,T0}$ = expansion coefficient in layer i at temperature T_0 (temperature at the start of the calculation)
D_{tot} = total thickness of the section





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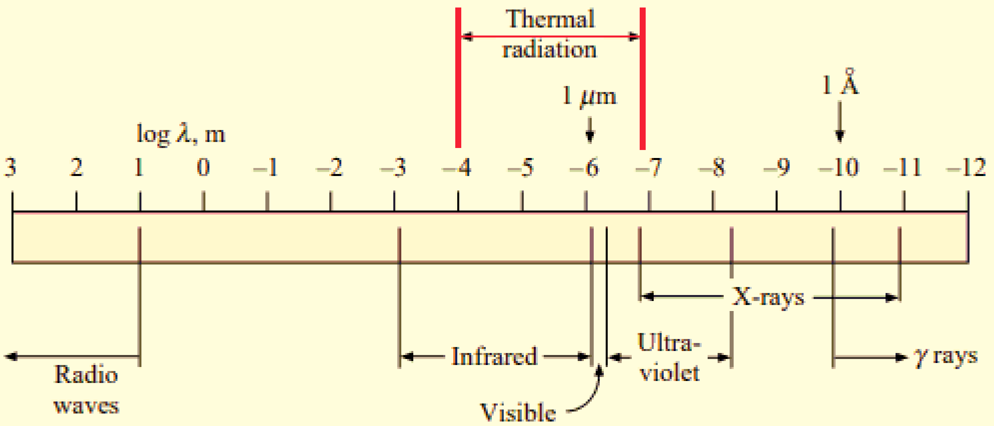
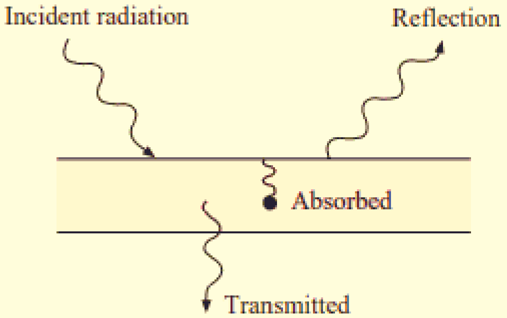
Further some figures for heat transfer by radiation:

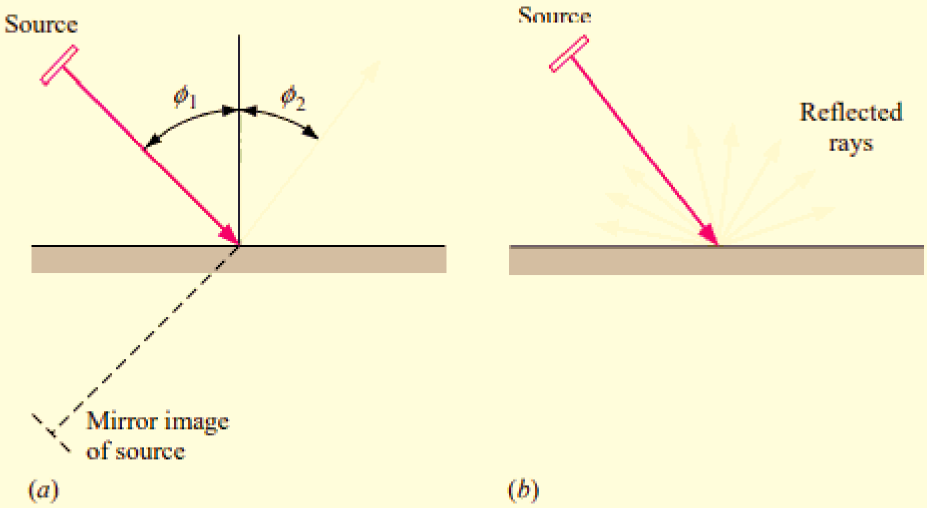
Electromagnetic spectrum.



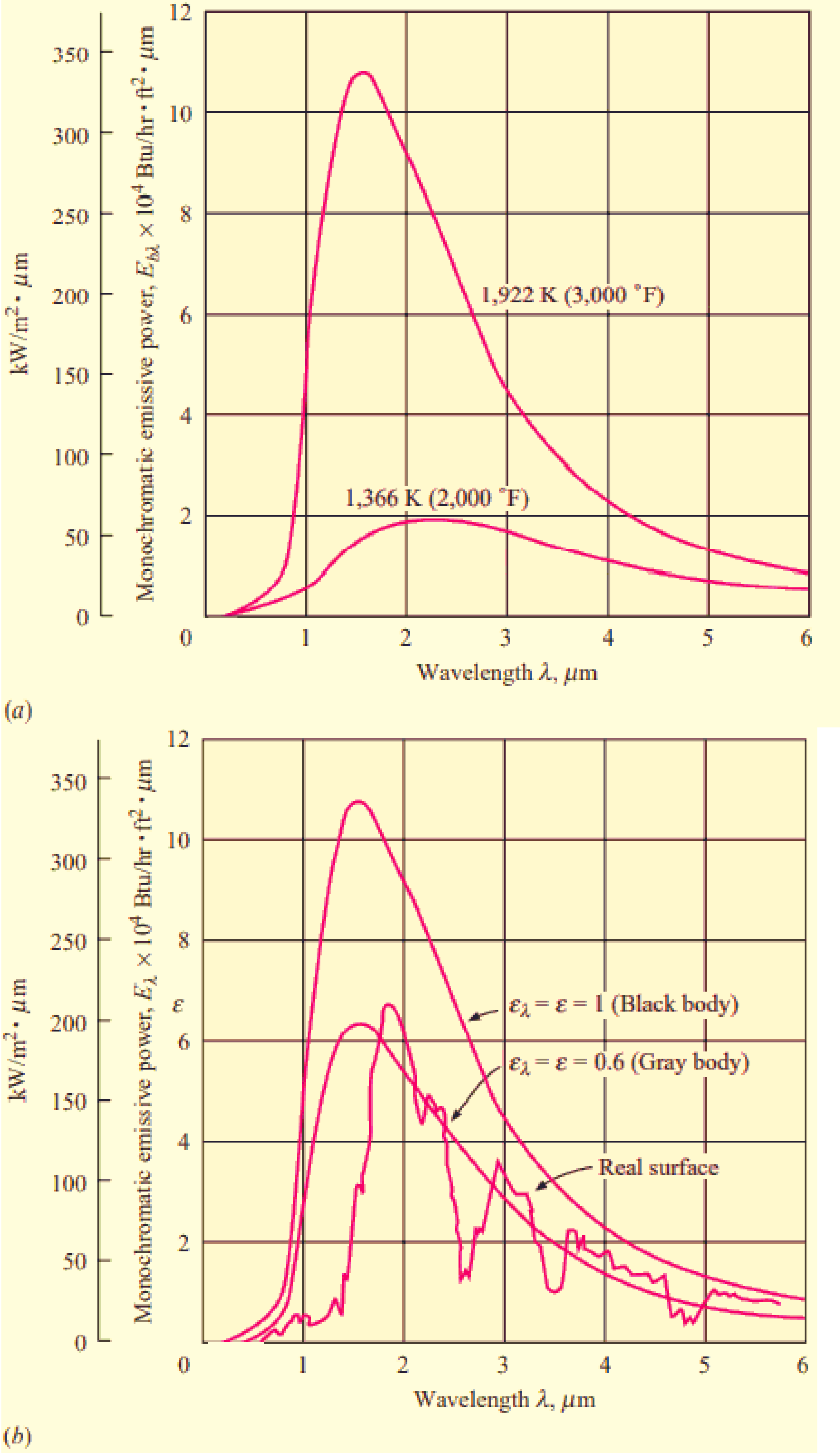
Sketch showing effects of incident radiation.



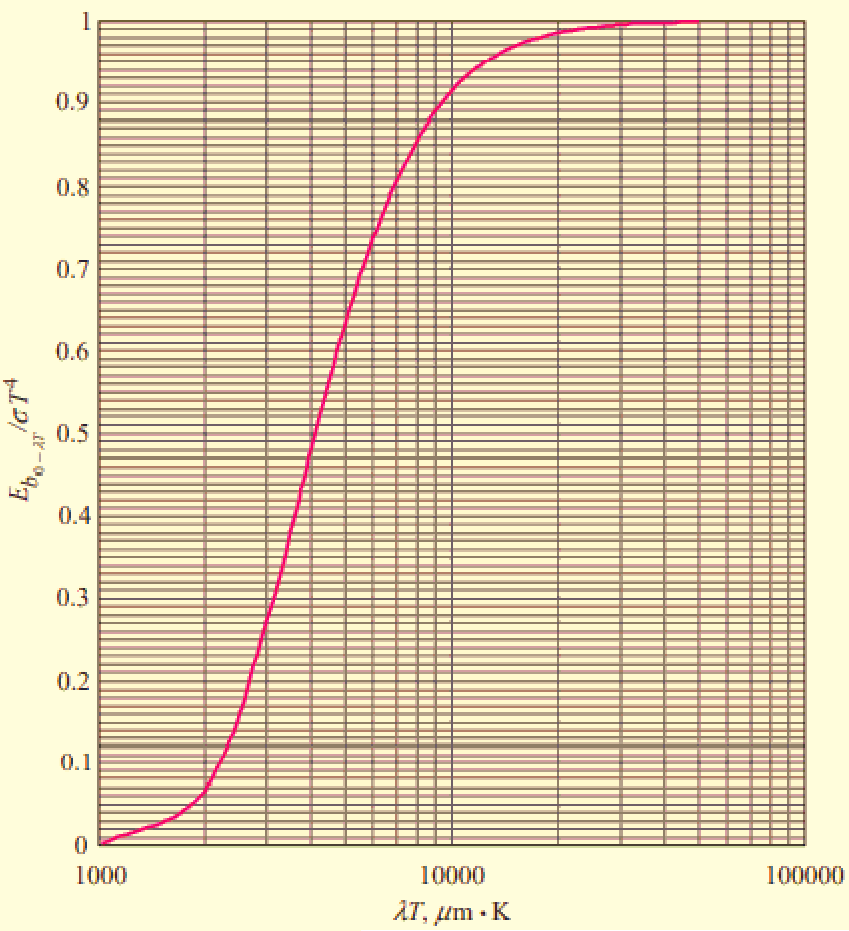
(*a*) Specular ($\phi_1 = \phi_2$) and (*b*) diffuse reflection.



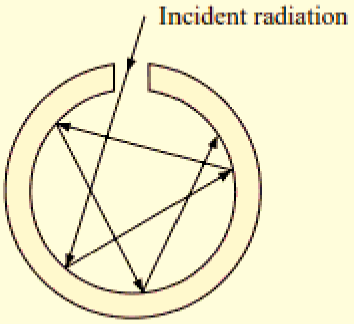
| (*a*) Blackbody emissive power as a function of wavelength and temperature; (*b*) comparison of emissive power of ideal blackbodies and gray bodies with that of a real surface.



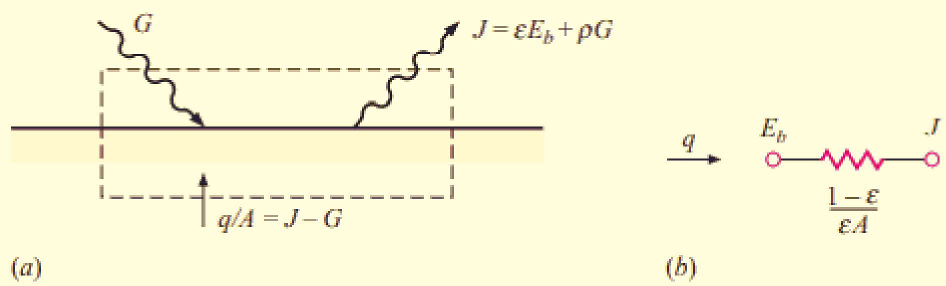
Fraction of blackbody radiation in wavelength interval.

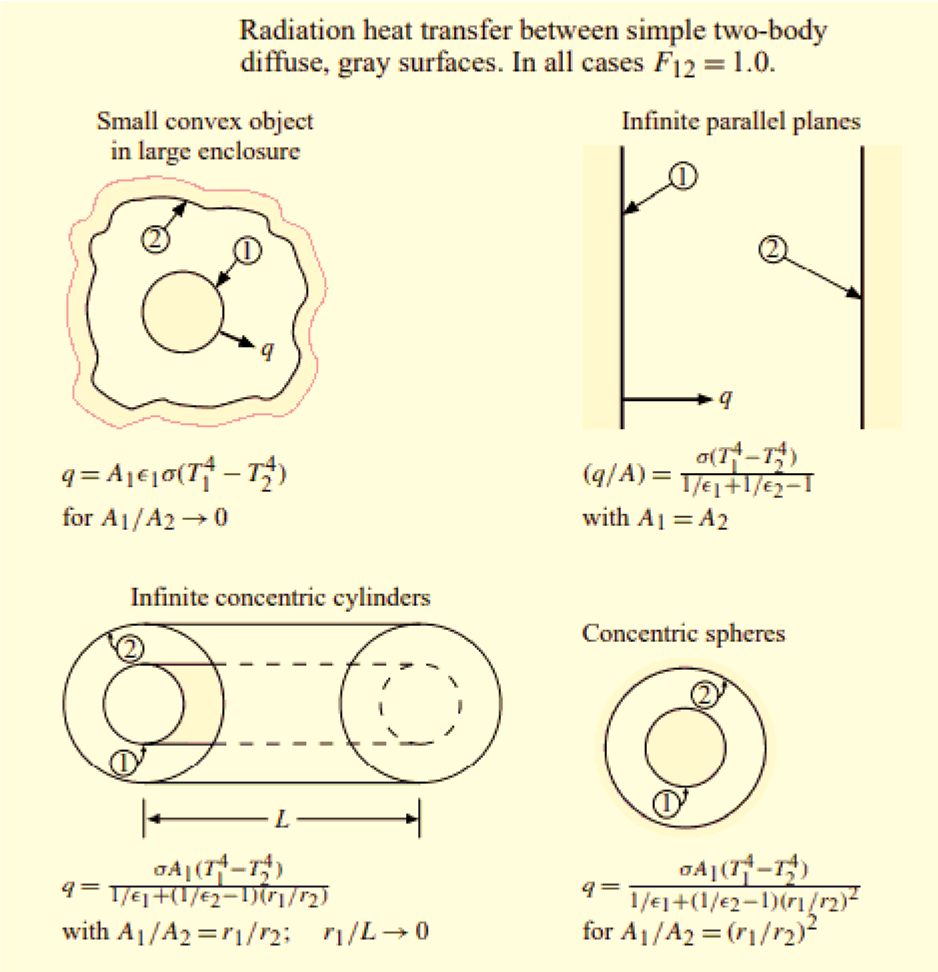


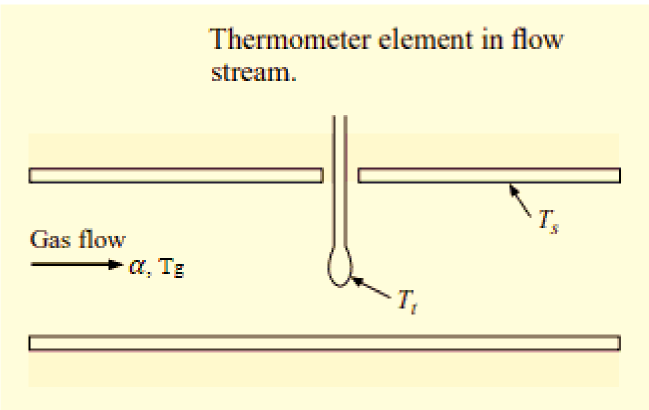
Method of constructing a blackbody enclosure.



(a) Surface energy balance for opaque material; (b) element representing "surface resistance" in the radiation-network method.



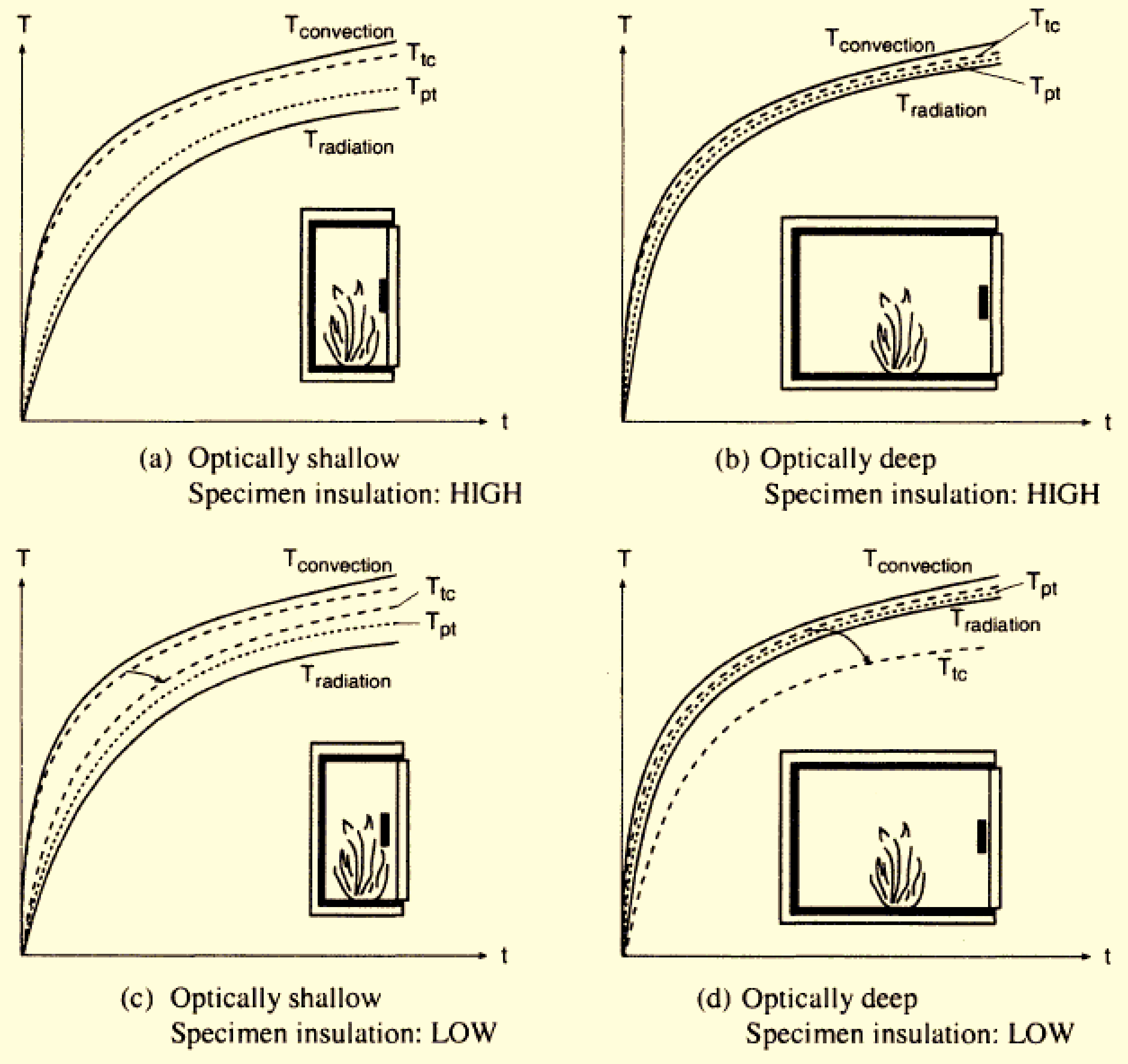


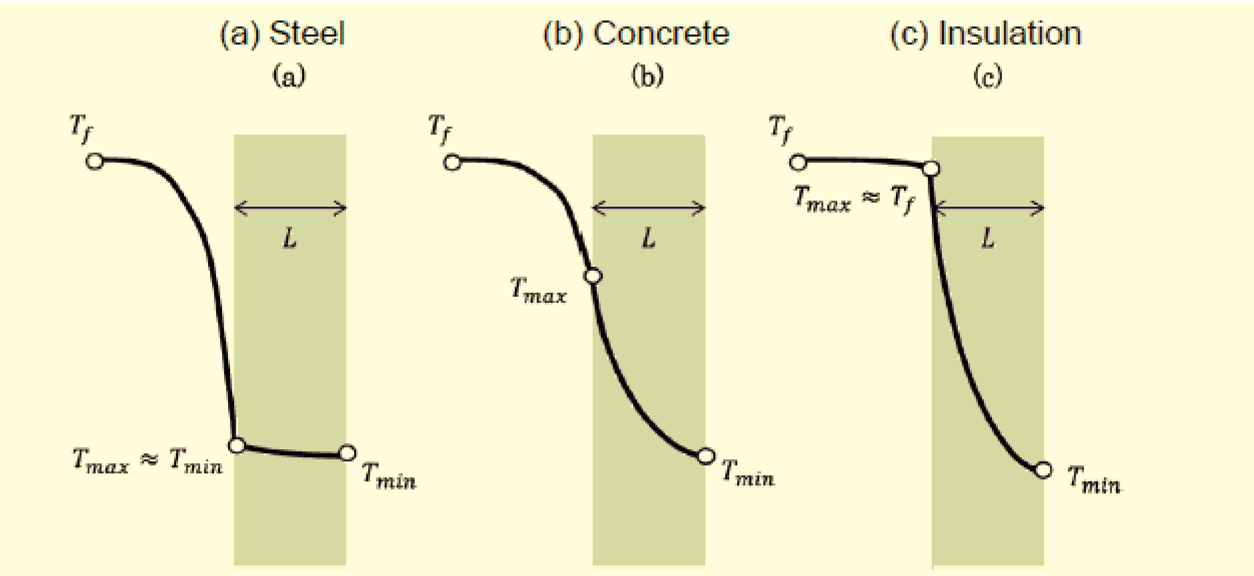


$$\alpha.(T_g - T_t) = \sigma.\varepsilon_s.(T_t^4 - T_s^4)$$

⇨ $T_g <> T_t$

From this energy balance we see that the temperature indicated by the thermometer T_t is not the true gas temperature T_g but some radiation-convection equilibrium temperature.





– TEMPERATURE DISTRIBUTION FOR DIFFERENT MATERIALS IN CASE OF FIRE
Adapted from Torero et al. [106]

$$q = \alpha.\left(T_s - T_f\right)$$