Transient simulation of kiln car with Simu-Therm 8.0

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Contents

About this tutorial

Simu-Therm 8.0 comes with a new expansion module for kiln cars which simplifies the transient simulation a lot.
This tutorial enables you to perform simulation of a kiln car independently.
You learn the new procedure step by step in two example applications
1.) kiln car running through a furnace, starting from cold state
2.) kiln car running in cyclic operation through a furnace

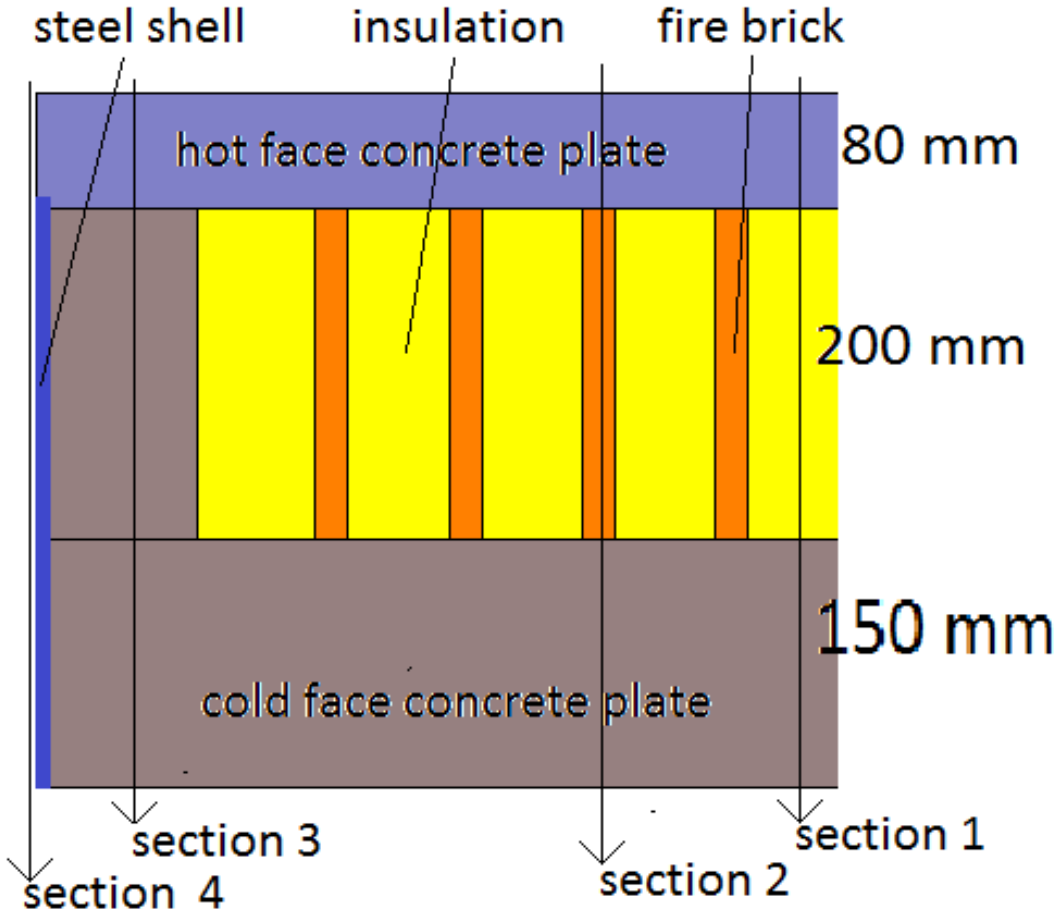
Kiln car simulation with Simu-Therm 8.0

In Simu-Therm 8.0 the heat loss of a kiln car is simulated with an expansion treating the kiln car as a plate composed of sections with different heat loss. Each of the sections is represented by a normal heat loss calculation. A transient simulation is performed simultaneously for all sections in which the heat loss and heat content of every section is accumulated according to its share of the kiln car area.
The simulation is based on the approximation that there is no mutual impact of adjacent sections.
The user should be aware that in reality there is an impact in the contact range of adjacent sections which always increases the total heat flow.

Sample kiln car

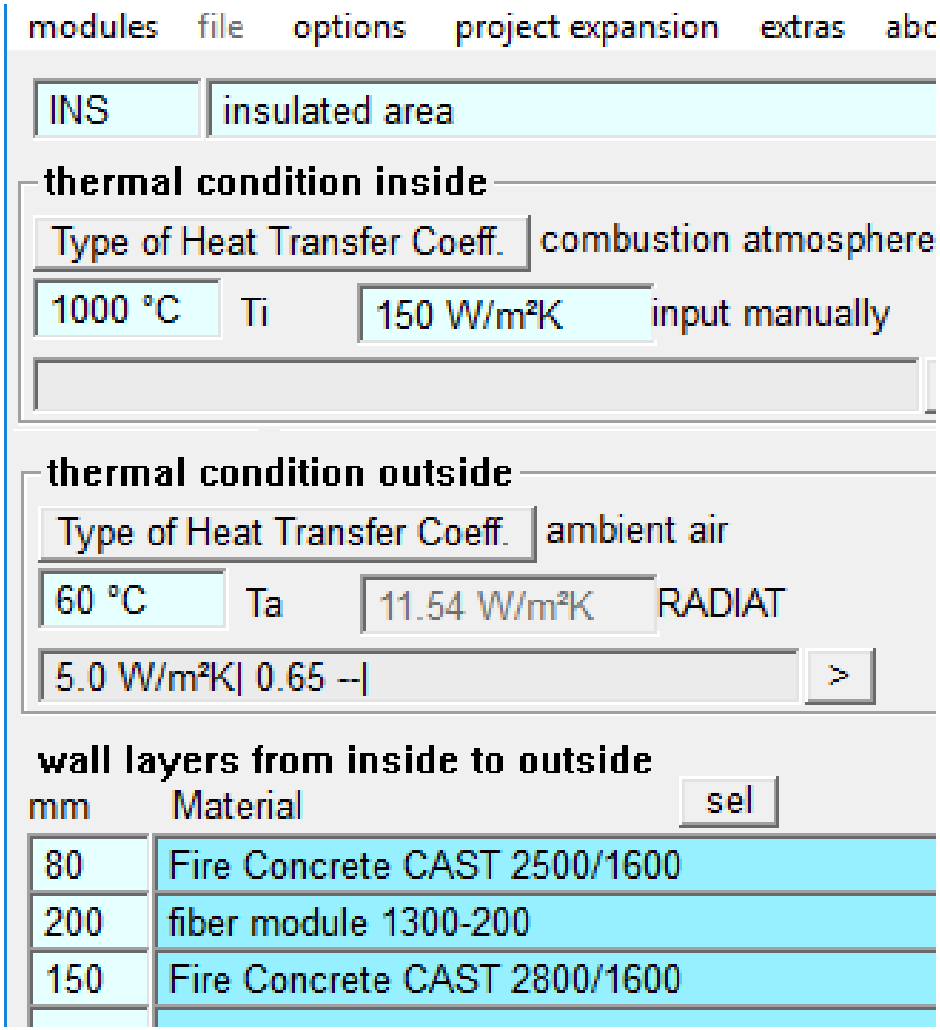
The sample kiln car for the tutorial is composed of 4 sections with different heat loss.

1. Insulated area
2. Bricks supporting the hot face plate
3. Concrete wall surrounding the car
4. Stell shell in the lower part.



Enter section 1 'Insulated area'

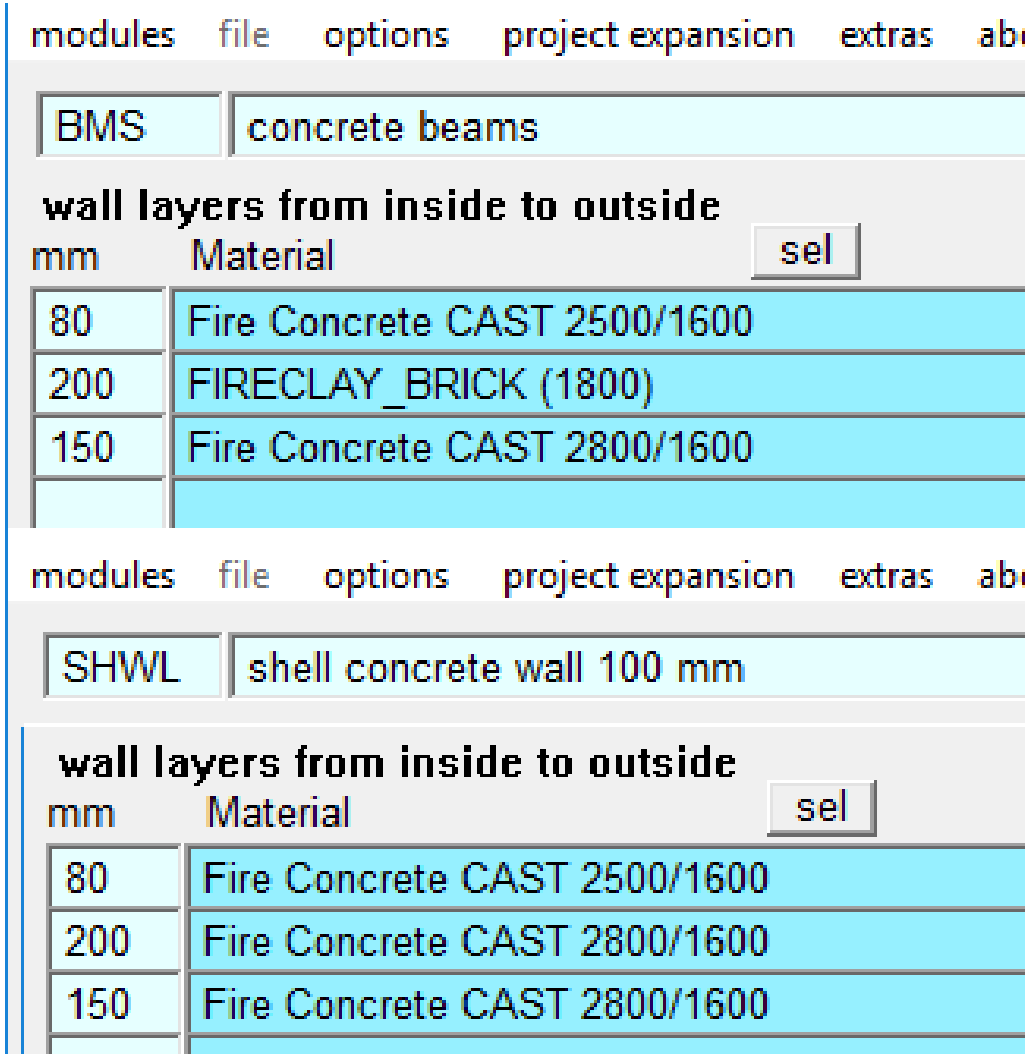
We distinguish four sections of the kiln car as shown in the previous sketch cap
1. we do not need to pay any attention neither to the type of heat transfer nor to the temperatures inside or outside. This is defined in the time schedule of the kiln temperature curve.
2. layers of the first section of the kiln car, 'Insulated area'.



Enter section 2 and 3

Enter the sections 2, 3 in the same way as before. Add descriptions in order not to mix up the sections.

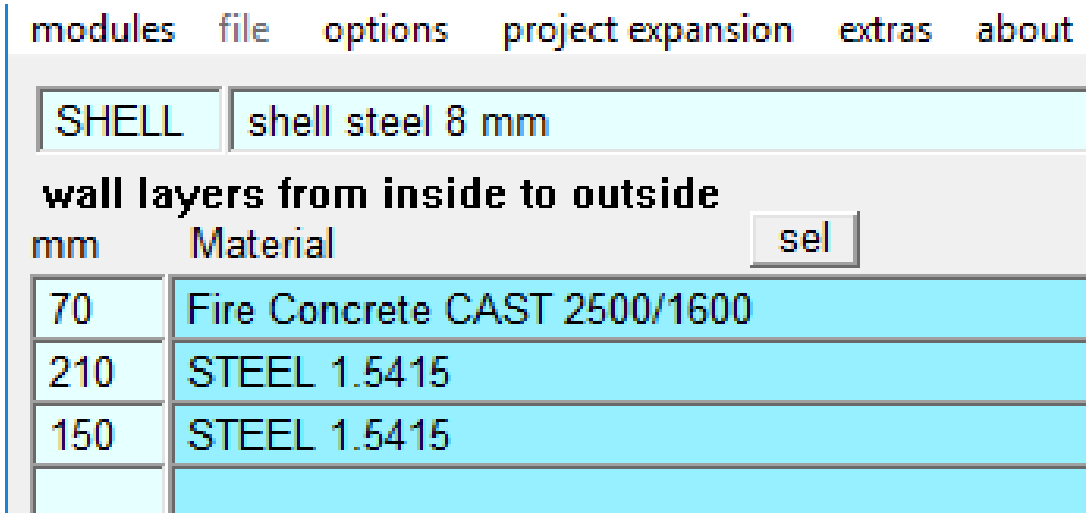
1. section 2 'Bricks supporting the hot face plate'
2. section 3 'Concrete wall surrounding the car



Enter section 4 'Steel shell'

Enter the insulation section for the steel shell.

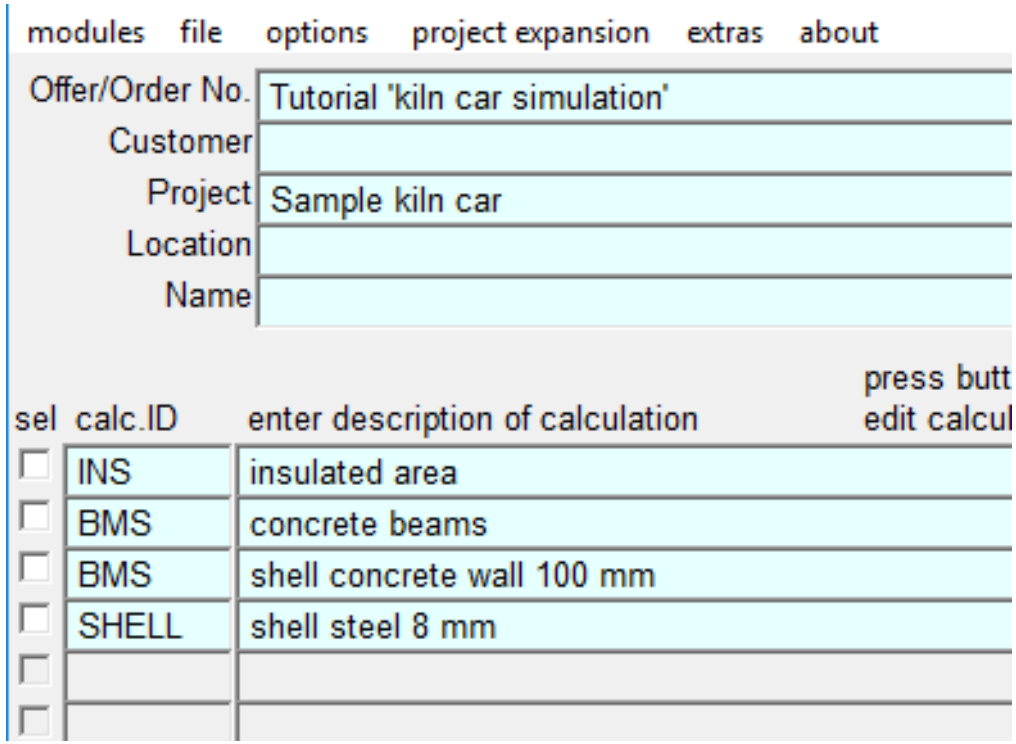
1. above the shell the thickness of the hot face plate is only 70 mm in place of 80 mm (sse the sketch above).
2. corresponding to that, 10 mm is added to the thickness of layer 2



Add a project expansion

Switch to the project page. The project should look as shown on the screenshot.

1. enter project information lines
Up to now, our project has no expansion mode. We treat kiln cars as plates and so we add the expansion mode *'sections are part of a plate (1 dimension)'* to our project.
2. click on dropdown menu *project expansion*

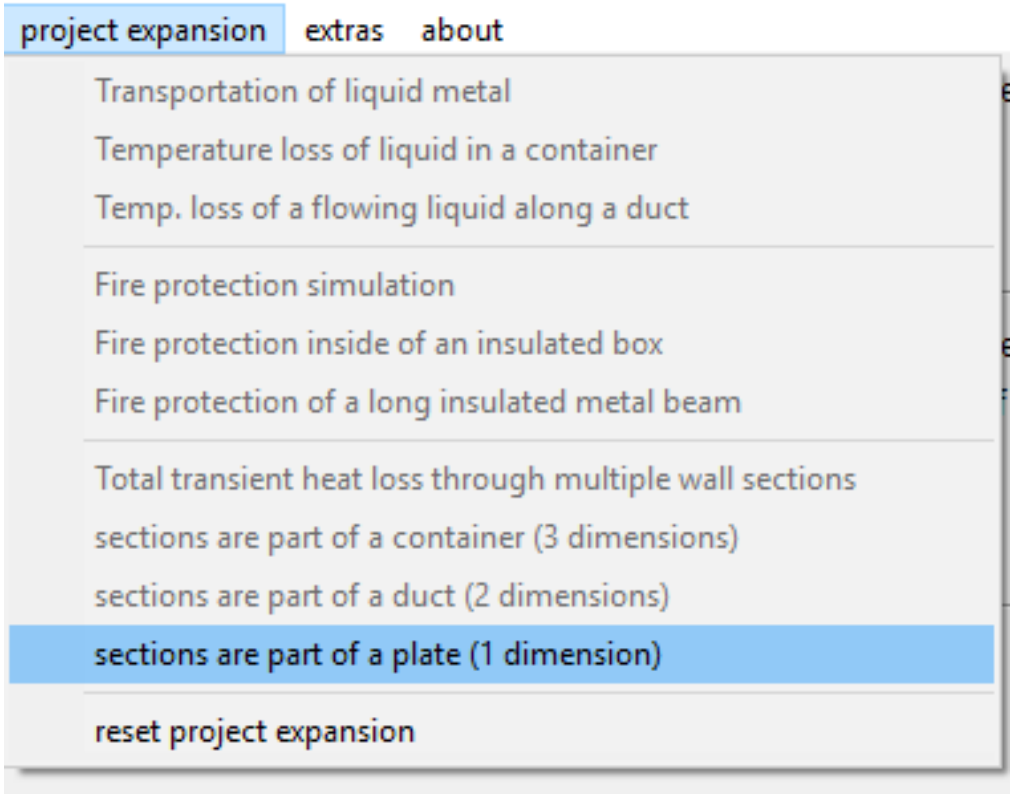


Project expansion 'Sections are part of a plate'

In the dropdown menu *project expansion* you can choose between several expansions with different features.

1. select *'Sections are part of a plate (1 dimension)'*

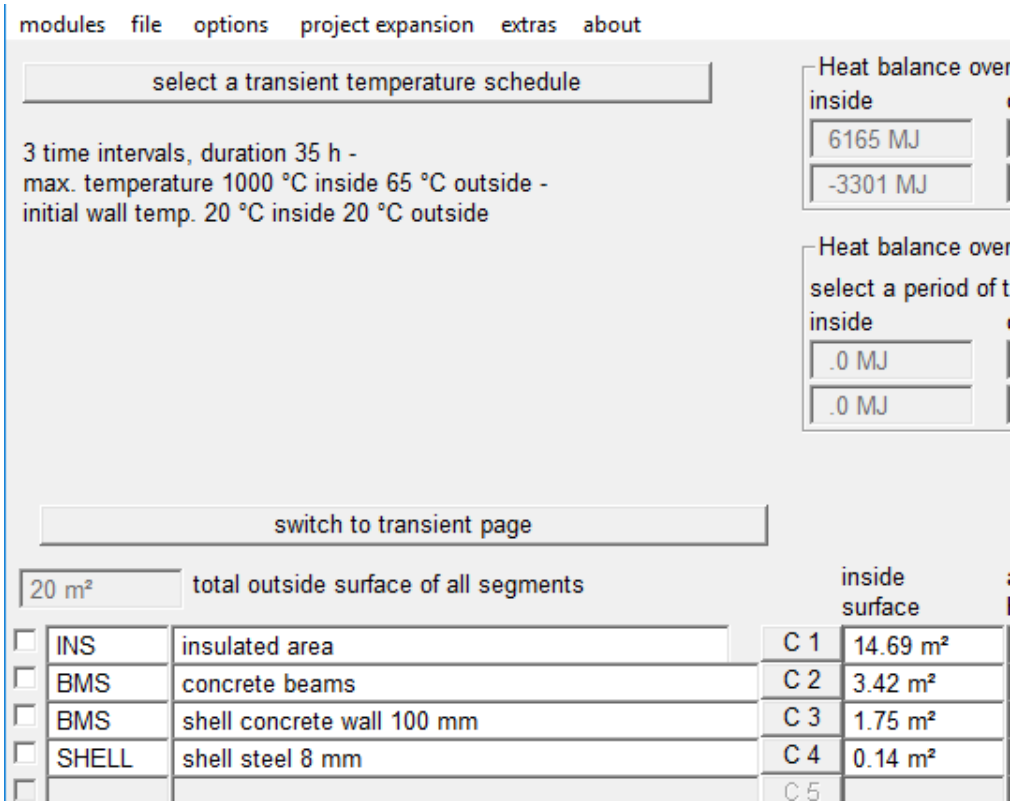
This is the expansion to simulate the heat loss and heat absorption of plates which are composed of different sections.



The kiln car simulation page

The kiln car simulation page controls working with the simulation. You can enter areas, select and modify a furnace temperature curve,launch the simulation and printing, view graphical results.

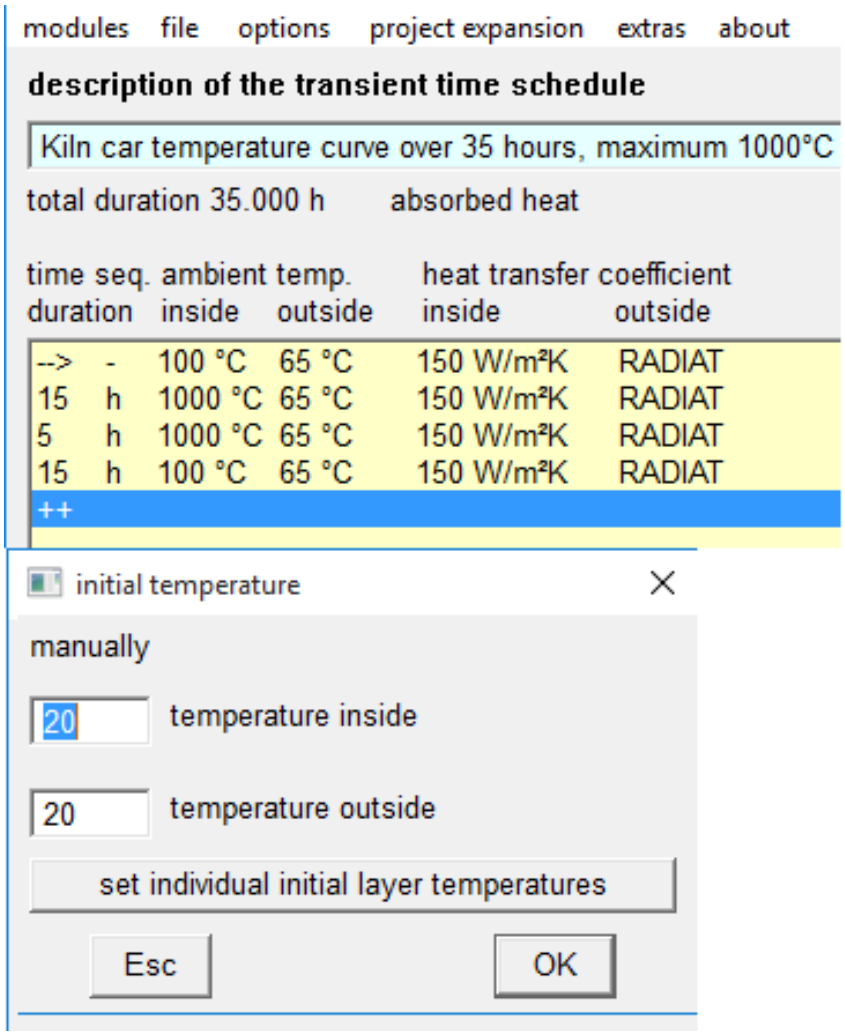
1. enter the inside areas of the insulation sections
2. click on *select a transient temperature schedule* and select the file **KilnCar_temp_curve.STtime**
3. click on *switch to transient page* to view the transient time table



The transient page for kiln cars

For details about the transient page see tutorial *Tutorial_transient.pdf*

1. duration of the schedule is 35 hours
The temperature in the kiln raises from 100°C to 1000°C within 15 hours, and is kept at 1000°C for 5 hours. Then the temperature drops back to 100°C
2. click on the button 'initial state' to enter the temperature of the kiln car before it enters the kiln.
assume that the kiln car was for a long time in ambient temperature, e,g. 20°C. Enter this inside for and outside.
3. enter 65°C as the temperature in the space below the kiln car.



Cold face heat transfer for kiln cars xx

For details about the transient page see tutorial *Tutorial_transient.pdf*

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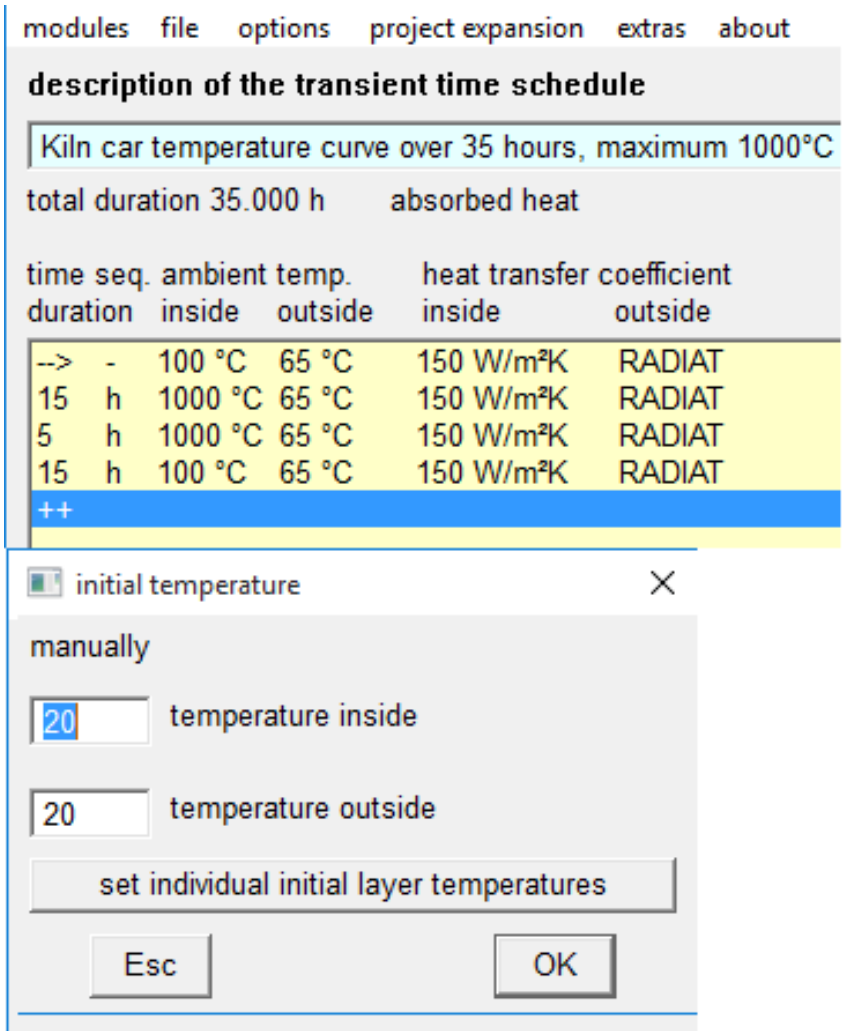
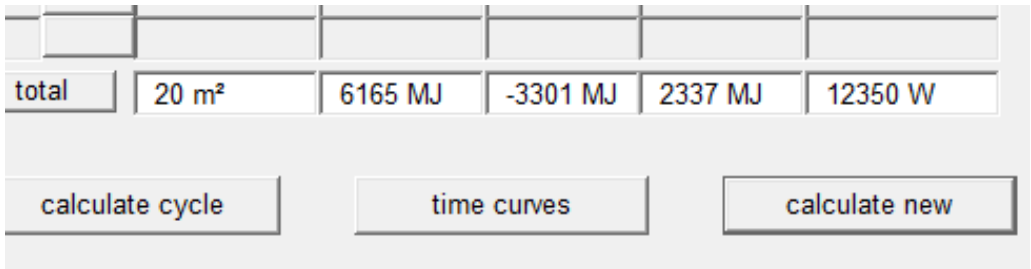


Simulate a cycle starting with a cold kiln car

If the simulation considers only one operation cycle, the initial kiln car temperature is taken from the temperature schedule (20°C). In this case the button **'calculate new'** is used.
If the temperature schedule considers the complete time up to the beginning of the next operation cycle, the remaing heat content in the kiln car can be taken into account by repeating the simulation of the cycle without resetting the kiln car temperature. Instead, the temperature at the end of the previous cycle is assumed. For this type of simulation the button **'calculate cycle'** is used.
Our current schedule does not consider the time between the exit of the furnace and the next entry into the furnace. So only **'calculate new'** is possible.

1. click on *calculate new* to launch the simulation



Simulation overview results

On the main page the simulation results of heat absorption and heat release during the simulated time are shown in MJ. Heat is absorbed when the furnace temperature is higher than the hot face surface temperature.

1. Absorption and release of heat at the hot face. Absorption occurs during the first 20 hours.
2. Heat balance cold face. There is a small heat absorption when the car is colder than the space below it.
3,4. Hot face heat balance of the sections.
5. Heat content of the kiln car at the end of the simulation.
6. Static heat loss, calculated with the mean temperature 614°C.

Heat balance over the total simulation time

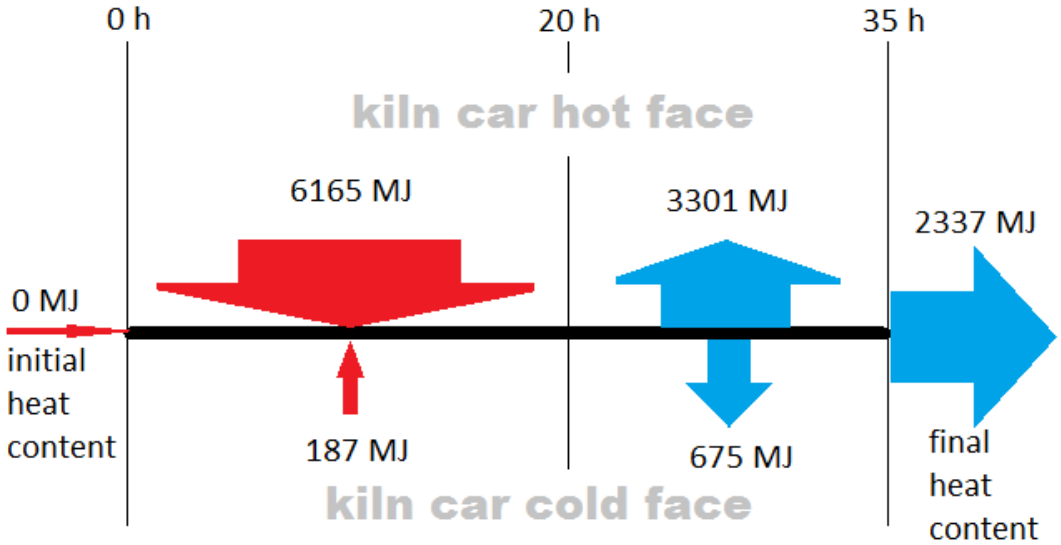
inside	outside	
6165 MJ	186.9 MJ	absorbed heat MJ
-3301 MJ	-674.8 MJ	heat release MJ

	inside surface	absorbed heat	released heat	content heat	static heat loss
1	14.69 m²	3618 MJ	-2681 MJ	945.8 MJ	2867 W
2	3.42 m²	1430 MJ	-438.8 MJ	732.5 MJ	4916 W
3	1.75 m²	969.9 MJ	-175.6 MJ	554.9 MJ	3847 W
4	0.14 m²	147.8 MJ	-5.139 MJ	103.5 MJ	719.6 W
	20 m²	6165 MJ	-3301 MJ	2337 MJ	12350 W

Kiln car heat balance

Heat flows per cycle - car enters the furnace in cold state

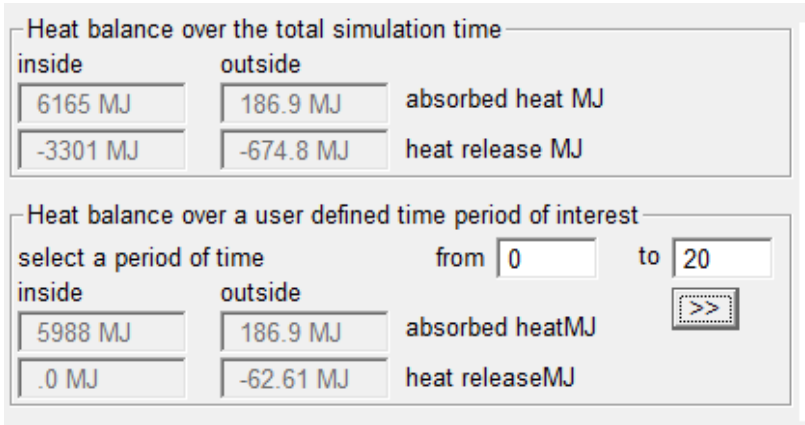
1. heat content of the kiln car before it enters the furnace. Zero if a cold car is emulated
2. heat absorbed at the hot face in the heating zone of the furnace.
3. heat release at the hot face.
4. heat release at the cold face.
5. heat content when the car exits the furnace, usually a major portion of the heat loss.



Main results of a selected time interval

The user can determine a time interval for which more information is needed. The same heat balance as for the complete time (see 1) is figured out for that interval. Click on the arrow button (2) to show the results. It is not necessary to repeat the simulation.

3,4. enter the beginning and the end of the time interval to be considered.
5,6. hot face: during the interval almost the whole absorption occurs, but no release of heat.
7,8. cold face: heat absorbtion merely occurs within the fires 20 hours, heat is released mainly in the last 15 hours.



Time diagrams of simulation results

When the simulation is performed, you can click the button **'time curves'** to view time diagrams of several figures recorded in the simulation.

1. use the arrow buttons to switch between diagrams
2. surface temperatures inside and outside
3. layer temperatures of the segments
4. total heat absorption inside and outside
5. total heat flow inside and outside
6. total heat content of the segments

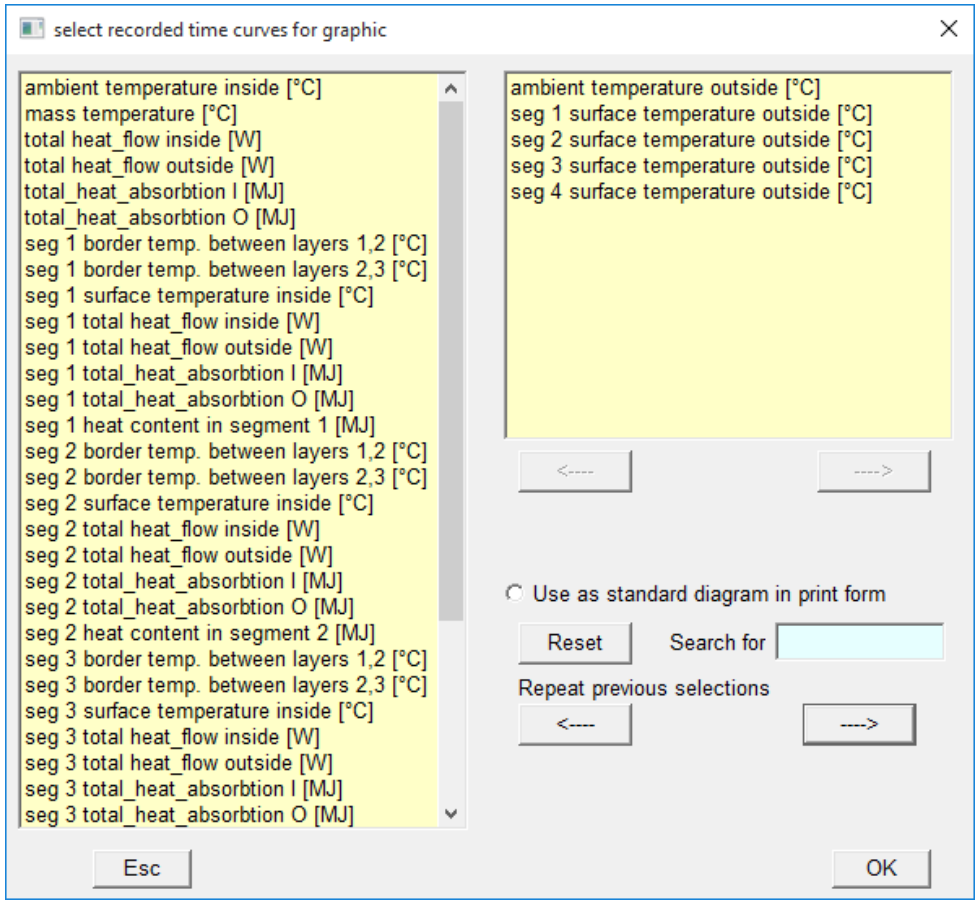


Diagram: Cold face temperatures over time

Cold face temperatures simulated independently for each segment. Due to a thermal exchange in the bottom plate the real temperatures are less different.

1. segment 1
2. segment 2
3. segment 3
4. segment 4

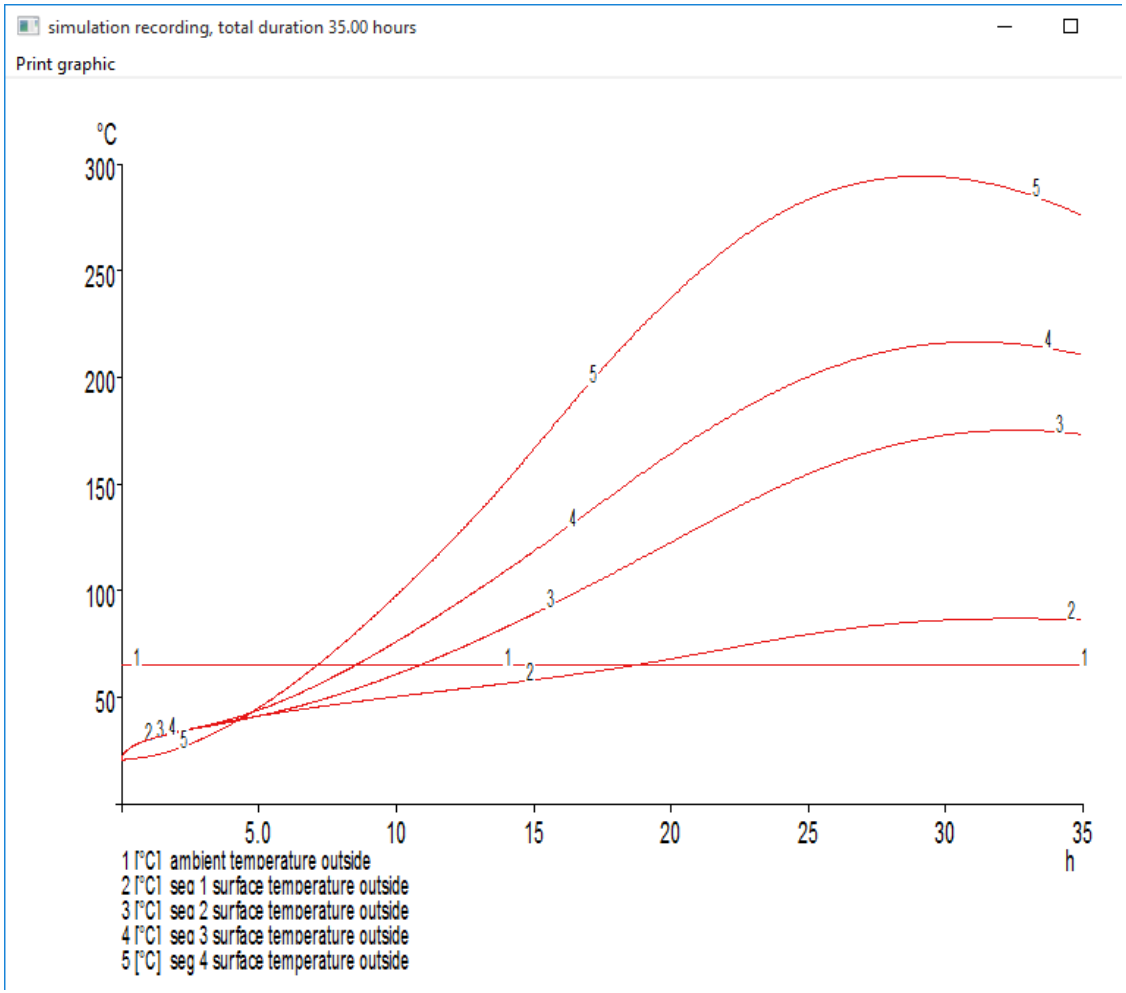


Diagram: Total heat absorption hot face

The total heat absorption on the hot face during the cycle reflects the amount of energy (in MJ) which a car draws out of the funace. In the cooling phase a portion of that energy flows back into the furnace.

1. segment 1
2. segment 2
3. segment 3
4. segment 4
5. sum of all segments

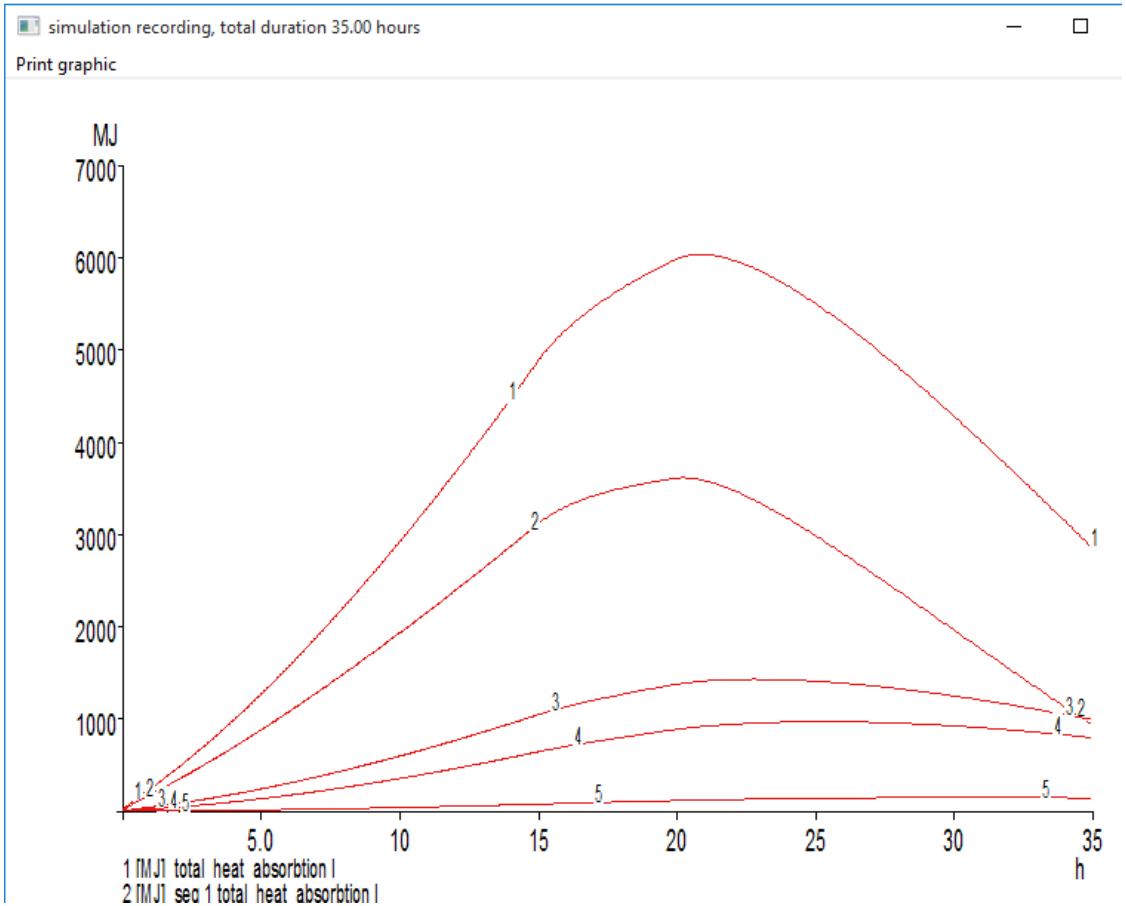


Diagram: Heat flow on the hot face

The heat flow on the hot face is given in Watt (Joule per second). The heat flow in the heating phase is delivered by the furnace burners. It can be used to estimate the additional burner power necessary for the kiln car.

1. segment 1
2. segment 2
3. segment 3
4. segment 4
5. sum of all segments

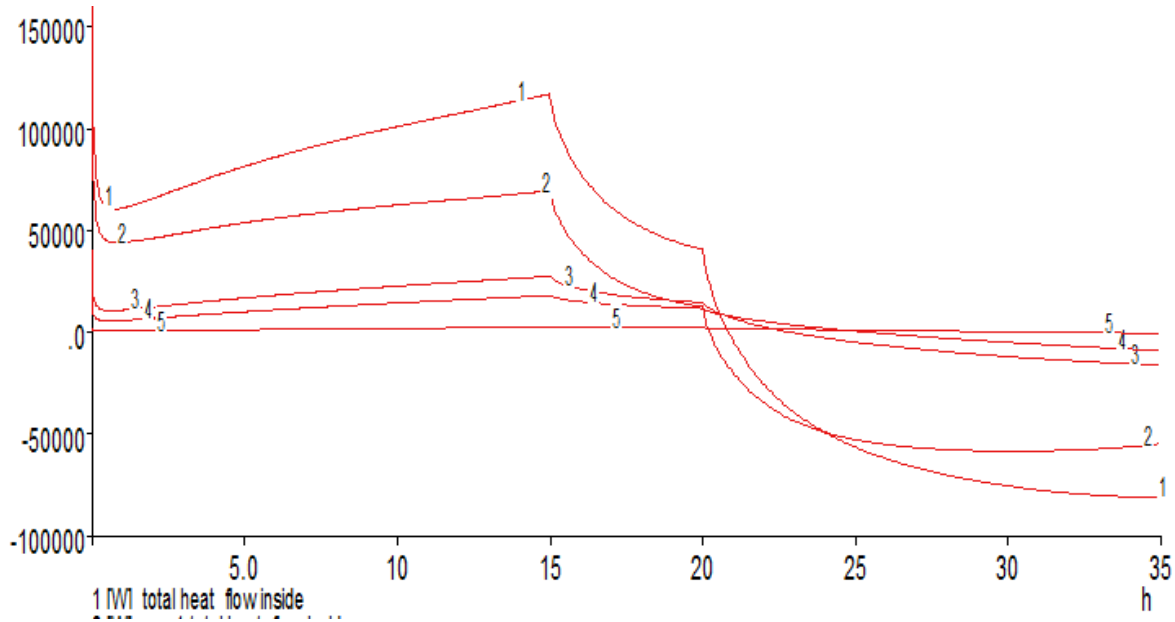
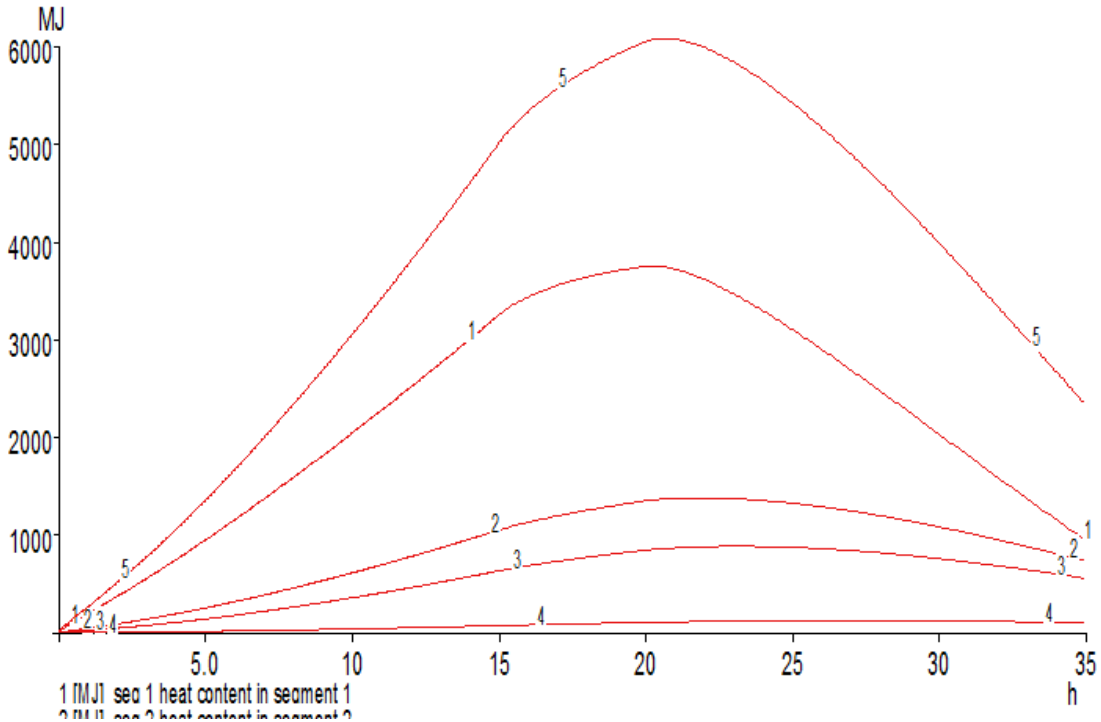


Diagram: Heat content of the kiln car over time

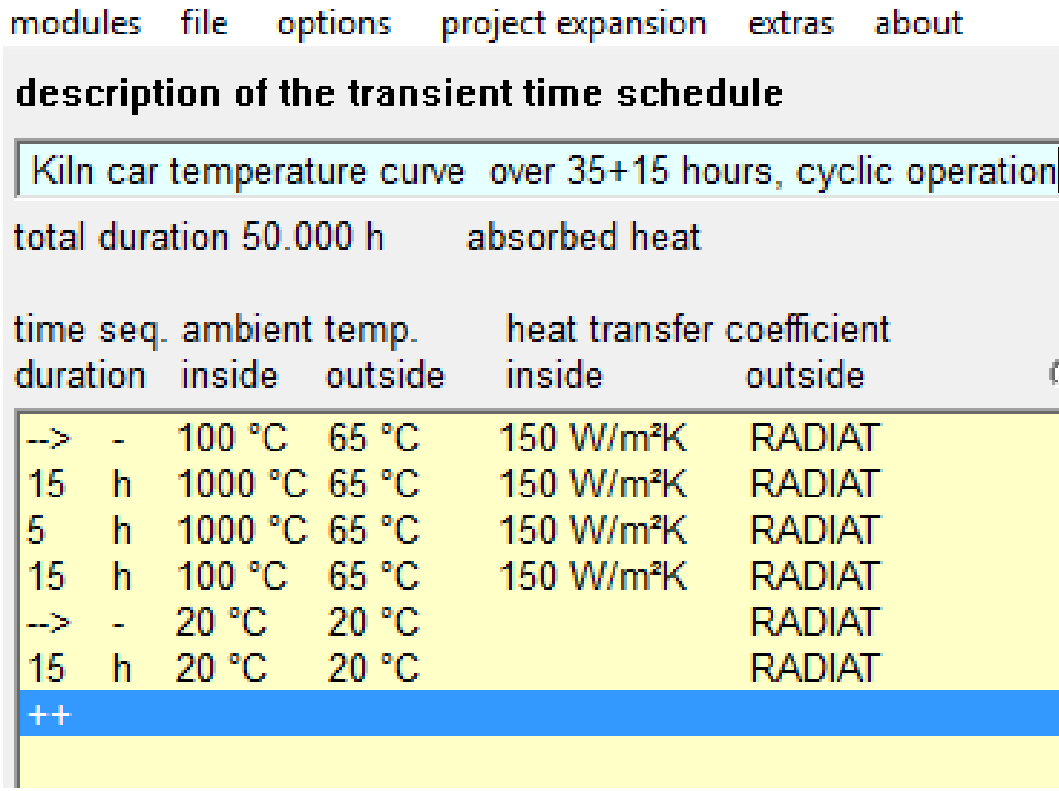
The content of the kiln car in MJ. The initial heat content is zero because the car enters the furnace in cold state.

1. total heat content of the kiln car (sum over all segments)
2. maximum heat content after about 22 hours
3. final heat content when the car exits the furnace.



Simulate a cylic kiln car operaton

1. switch to the transient page and append a 15 hours time period outside the furnace (step 0 h to change conditions and step 15 h at the end of the interval)
2. this time the maximum temperature in the box is 186°C, much better than for an empty box, but still too hot. On the simulation page click once on calculate new and several times on calculate cycle until the results are stable.



Heat balance of the cyclic operation

How has the heat changed in the cyclic operation compared to the first cycle?

1. in order to compare the time in the furnace we consider the first 35 hours as 'time period of interest'.
2. the kiln car absorbs about 450 MJ less from the furnace.
3. the remaining heat exits the car completely on cold side, where the heat loss has increased. The heat content of the car at the furnace entry is the same as it is at the exit.

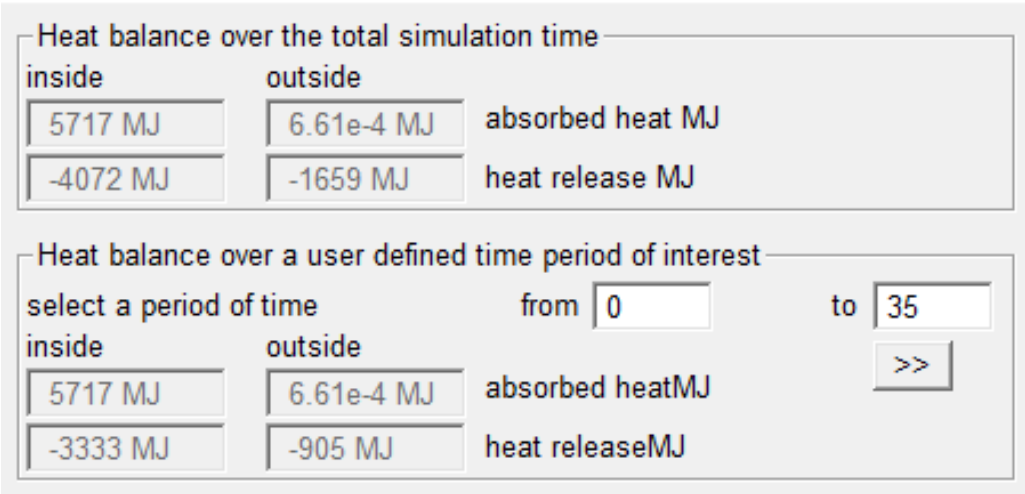


Diagram: Total heat absorption hot face

The total heat absorption of the cyclic simulation is slightly different from the single-cycle simulation above

1. the total heat absorption is a bit lower
2. outside the furnace there is slower drop of heat because the surface is not cooled with fans

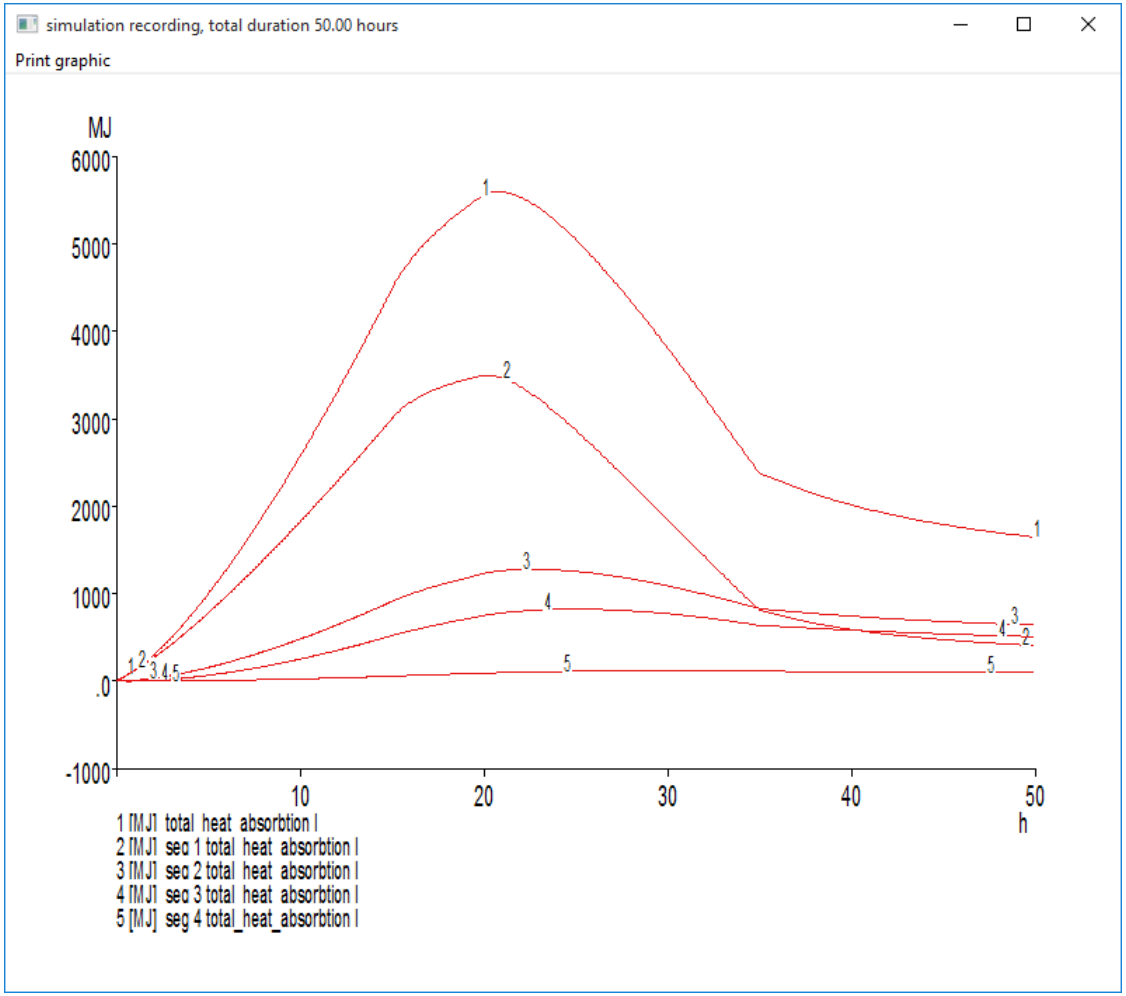


Diagram: Heat content of the kiln car

Again we compare to the single-cycle simulation above.

1. the maximum heat content absorption is a bit higher
2. the initial heat content is the same as the final one (at the of the previous cycle). So the kiln car enters the furnace with a higher heat content than above