ForglassBox

21st century technological support for glass producers

What does this app do and who is it for?

ForglassBox is the first application of its kind that performs technological glass calculations on a smartphone. It makes it possible to:

- Calculate the raw materials for a batch, from which, flint, amber, green and olive glasses with a given chemical composition can be melted, with the use of selected raw materials and constraints (boundary conditions)
- Calculate the technological and physicochemical properties of these glasses.

Given for each of these glasses are: default chemical composition, recommended selection of raw materials and the boundary conditions that allow each type of glass to be obtained during melting in an industrial furnace. The calculations are performed using equations tested in industrial practice.

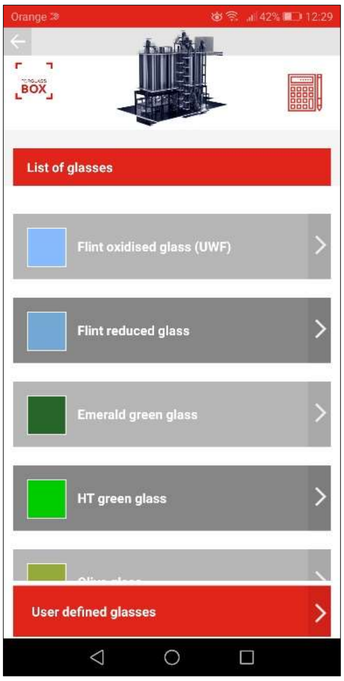
The aim of the developers of the application was to turn the modern smartphone into a handheld computing centre for a technologist. Unlike the computer, smartphone is a device that all manufacturers, processors and users of glass, as well as designers of equipment for the glass industry carry in their pocket and can access anywhere and at any time. The application is “smart”, which means that when calculating the proportions of individual raw materials, it takes into account not only the given chemical composition, but also the Batch Redox Number, necessary to obtain the expected colour of glass and optimizes the amount of sulphates, taking into account the needs of fining and SO_3 saturation concentration in the glass of the given colour after forming. The application compares the chemical composition of the glass selected for calculations with the compositions of the raw materials selected for the batch and suggests the necessary corrected proportions of $Al_2O_3/(Al_2O_3+SiO_2)$, $K_2O/(K_2O+Na_2O)$ and $MgO/(MgO+CaO)$. The calculated glass properties can be used for setting the temperature profiles for melting, fusing, tempering and annealing, optimizing the furnace’s thermal power requirements from combustion space and boosting, as well as furnace geometry.

Application architecture

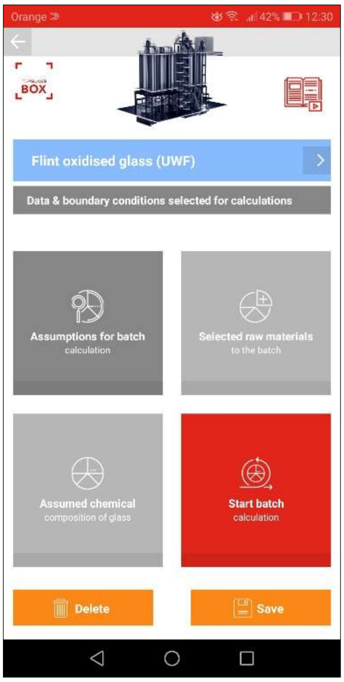
The architecture of the application is user-friendly, offering less advanced users the option to select any of the default packages from an extensive list, while advanced technologists can modify most of the parameters in order to adapt them to the specific requirements of the production facility, local raw materials and their own habits. For the first group, a glossary of terms used in the application and in glass practice is included. For the second group of users (although certainly not limited only to them), the application provides a constantly updated list of innovative and tested solutions from Forglass.

Step-by-step instructions for calculating batch raw materials to produce glass with defined chemical composition.

Step 1. On **screen 1**, click the **BATCH CALCULATION from chemical composition of glass** button and continue to screen 2.



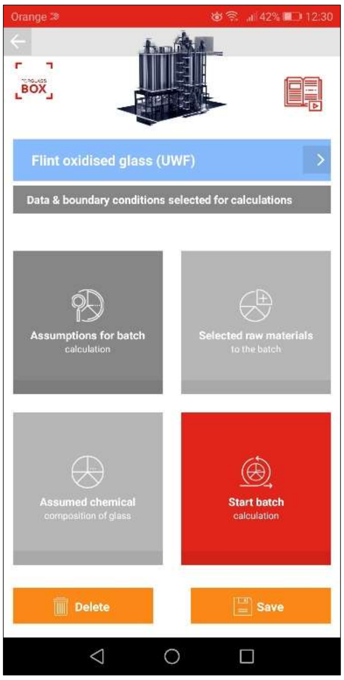
Step 2. On **screen 2**, from the list of glasses [**Flint reduced glass, Flint oxidised glass (UWF), Olive glass, Amber glass, Emerald green glass, HT green glass**], click the > symbol to the right of the glass, for which you want to calculate the batch. If you want to perform additional or new calculations/operations on glasses, for which you've already made calculations and saved them in **User-defined glasses** collection, click that button at the bottom of the screen. If you want to return to the previous screen, click the arrow at the top left of the screen. You can return to the start screen at any time by clicking the **FORGLASS BOX** icon at the top left of the screen.



Step 3. **Screen 3** contains data and boundary conditions for the desired calculations: **Assumed chemical composition of glass, Assumptions for batch calculation, Selected raw materials**. To modify the chemical composition of glass, click the **Assumed chemical composition of glass** button.

Step 4. **Screen 4** contains fields to select the concentration (as [wt %]) of glass components: **SiO_2, Al_2O_3, Na_2O, K_2O, MgO, CaO, MnO, Fe_2O_3, TiO_2, Cr_2O_3, CeO_2 and SO_3** and the maximum allowable deviation of those oxides (down **Δ-** or up **Δ+**) in the glass melted from the batch calculated with the boundary conditions for selected raw materials – see **screen 6**. To modify the concentration of a specific component, click the **Edit** button below the data section of a given oxide.

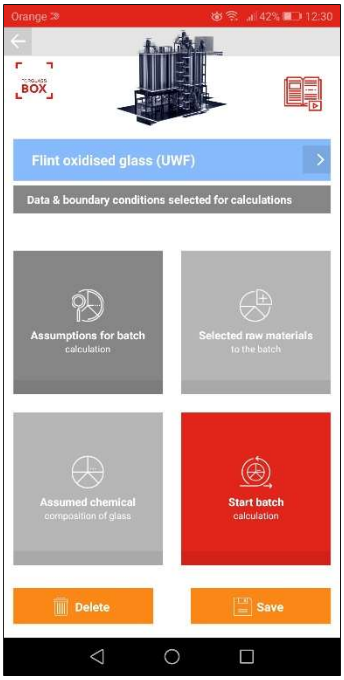
Step 5. After selecting the specific component of glass on **screen 5**, it is possible to change its concentration and the value for the maximum allowable deviation of those oxides (down **Δ-** or up **Δ+**) in the glass. To save the changes, you must click the **Change** button. To discard changes, click the **Back** button.



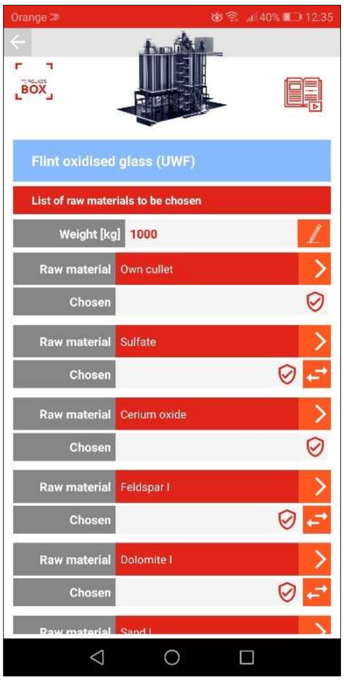
Step 6. After entering the concentration values for all components of the glass, click the arrow on the top left to return to **screen 3**, where you can click the **Assumptions for batch calculation** button to modify the minimum and maximum values for the **Batch Redox Number, final SO_3, fining SO_3 and amount of own cullet in the batch**. Changes in the assumptions for calculation can be made on **screen 6**.

Step 7. **Screen 6** shows the assumptions for calculations, which can be edited by the user after clicking Edit button to the right of the selected set of values – see **screen 7**. The default values in each set are the most typical ranges of **BRN, final SO_3** and **fining SO_3** for the selected glass type. To save the changes, click the **Change** button; to discard the changes, click the **Back** button.

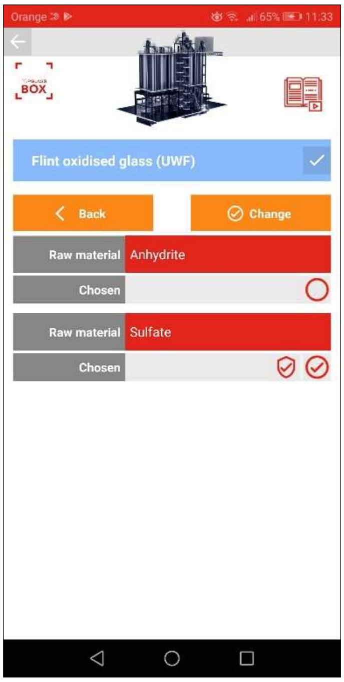
Step 8. On **screen 7**, the user can modify the values for **BRN, final SO_3** and **fining SO_3**, keeping in mind that setting values outside of the typical range for a given colour of glass can make it impossible to achieve. Also, setting values for **SO_3** that are too low or too high may result in technological problems such as not satisfied-fining or foam on glass surface. To save the changes, you must click the **Change** button. To discard changes, click the **Back** button.



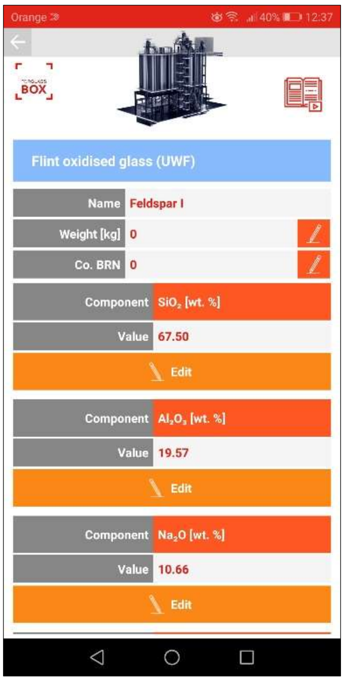
Step 9. After entering the concentration values for all components of the glass, click the arrow on the top left to return to **screen 3**, where you can click the **Selected raw materials for batch** button to make your selections, change their chemical composition.



Step 10. **Screen 9** contains the list of raw materials selected for batch calculation. The user can modify composition of selected raw materials by clicking the **>** symbol to the right of the name of the material. Materials with alternatives have the additional ⇆ button that can be clicked to reveal **screen 10**, which allows the user to choose alternate material.

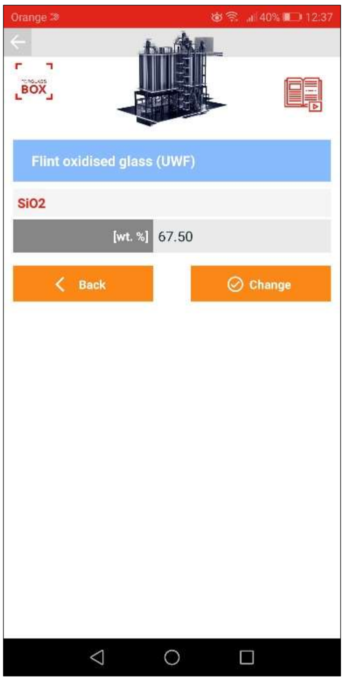


Step 11. **Screen 10** shows a sample list of alternate raw materials for chosen batch calculation. To change the material, click the ◯ circle next to the **Chosen** window.

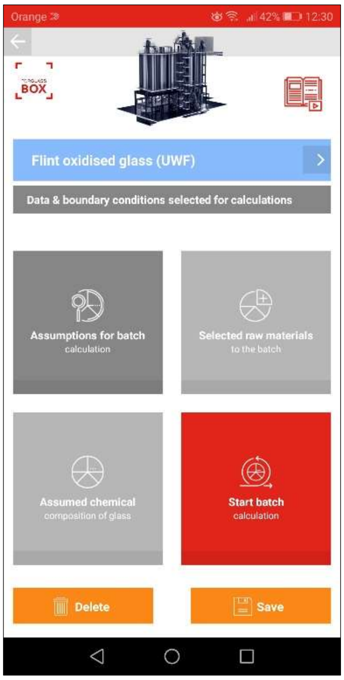


Step 12. **Screen 11** shows properties of a sample of raw material selected for batch calculation. User can adjust (change) the concentration of various oxides, according to the chemical composition of the raw material to be used in the batch. To make changes, click the icon next to the field you wish to edit.

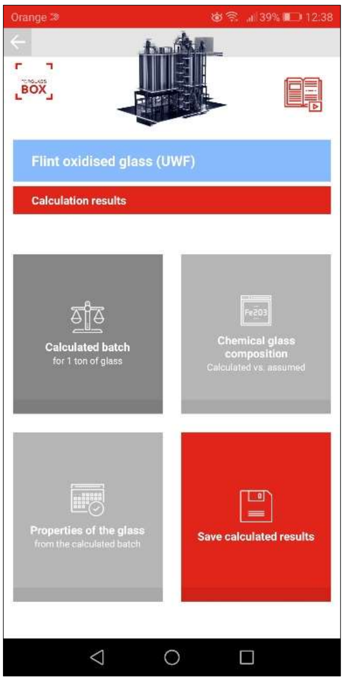
If you want to discard the changes, simply click the **Back** button.



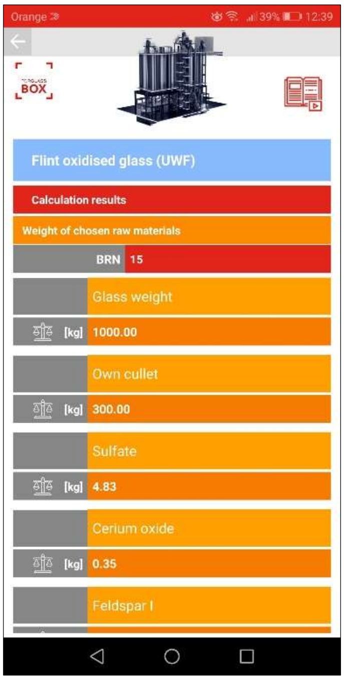
Step 13. **Screen 13** shows the window for editing composition of a sample of raw material selected for batch calculation. User can change the concentration of a component by entering the new value in the field and clicking **Save**. If you want to discard the changes, simply click the **Back** button. Similar operations can be performed for other components of the raw material.



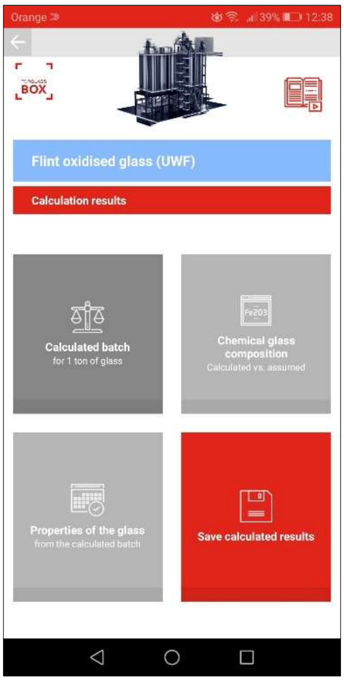
Step 14. After making all the necessary changes in 1) chemical composition of glass; 2) limits (boundary conditions); 3) raw materials selected for the batch; and 4) their names and chemical composition, user can click the **Start batch calculation** button on **screen 3**.



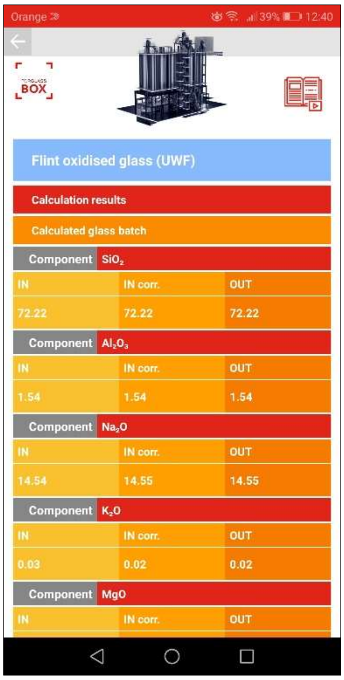
Step 15. The results of the calculation can be accessed on **screen 14**. After clicking the **Calculated batch** button, the total weights of all the raw materials can be seen for the defined amount of glass/batch/sand, which must be used to achieve glass with a defined composition.



Step 16. **Screen 15** shows the batch calculated for the user-defined amount of glass/batch/sand.

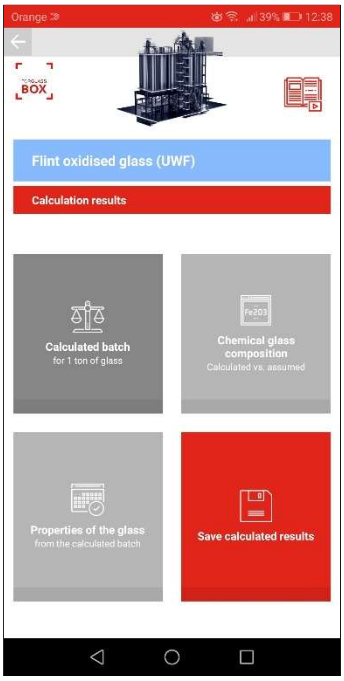


Step 17. The results of the calculation can be accessed on **screen 14**. After clicking the **Chemical composition of glass** button, next screen appears.

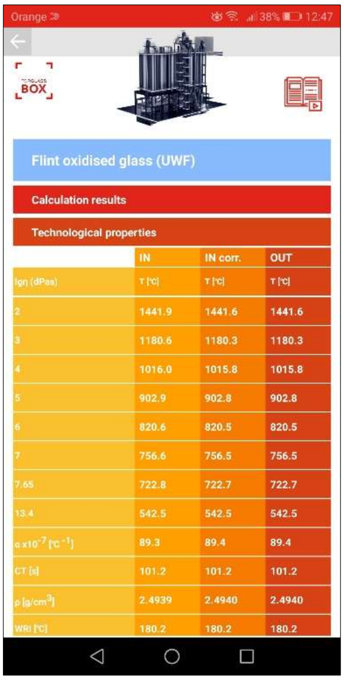


<u>Step 18</u>. **Screen 16** shows the chart for chemical composition of glass:

- **IN**: selected by user for calculations
- **IN corr.**: selected by user after correcting the concentration of Al_2O_3, K_2O and MgO to levels possible to achieve from selected raw materials
- **OUT**: resulting from the batch calculated by the application



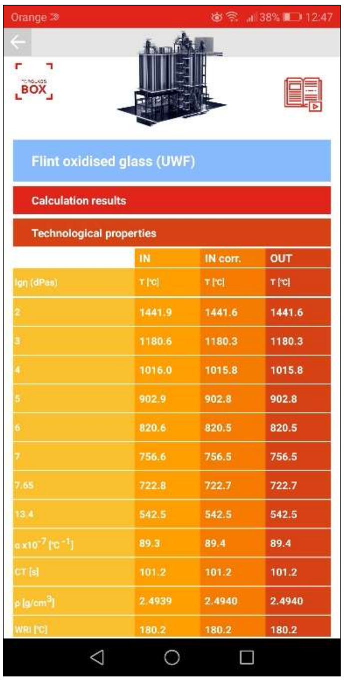
<u>Step 19</u>. The results of the calculation can be accessed on **screen 14**. After clicking the **Properties of the glass** button, **screen 17** shows the list of calculated values.



Step 20. **Screen 17** shows the list of calculated values:

- Technological
- Additional technological
- Specific electrical conductivity
- Specific heat
- Specific heat conductivity

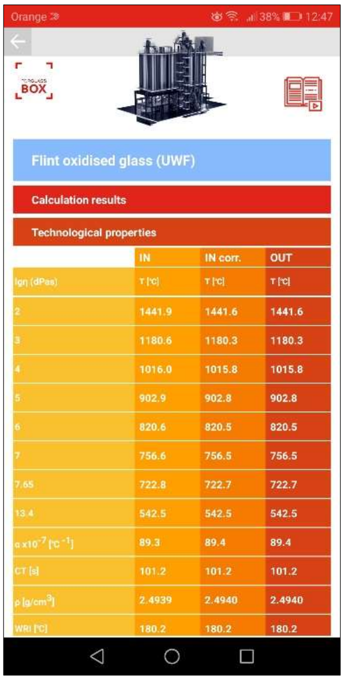
In iOS version, to display the calculation results for a selected group of properties, click the > icon on the right.



Step 21. **Screen 17** shows the list of calculated technological properties:

- Temperatures relative to viscosity
  - 100 dPas (lgη=2)
  - 1 000 dPas (lgη=3)
  - 10 000 dPas (lgη=4)
  - 100 000 dPas (lgη=5)
  - 1 000 000 dPas (lgη=6)
  - 10 000 000 dPas (lgη=7)
  - Littleton Point (LP = 44 668 359,2 dPas; lgη=7,65)*
  - Anealing Point (AP = 25 118 864 315 095,9 dPas; lgη=13,4)*
- Cooling time (CT)*
- Working Range Index (WRI)*
- Relative Machine Speed (RMS)*

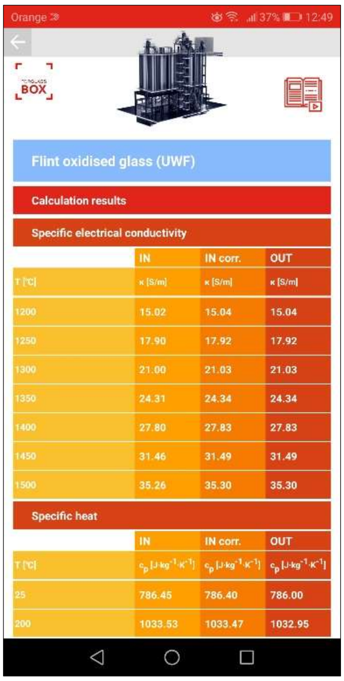
* – definitions of terms used can be found in the Glossary of terms – see the main screen of the application



<u>Step 22</u>. **Screen 17** shows the list of calculated, additional technological properties:

- Rigid gob temperature (RGT)*
- Liquidus temperature (T_{liq})*
- Primary phase crystallisation field (most probable crystalline phase appearing during glass crystallisation)*
- The temperature gap between rigid gob temperature - RGT and liquidus temperature (Δ RGT – T_{liq})*
- The temperature gap between temperature corresponding to viscosity for lgη=3 and liquidus temperature ($\Delta T_{lg\eta=3} - T_{liq}$)*

* – definitions of terms used can be found in the Glossary of terms – see the main screen of the application



<u>Step 23</u>. **Screen 20** shows the calculated values of specific electrical conductivity at temperatures of: 1200, 1250, 1300, 1350, 1400, 1450 and 1500°C

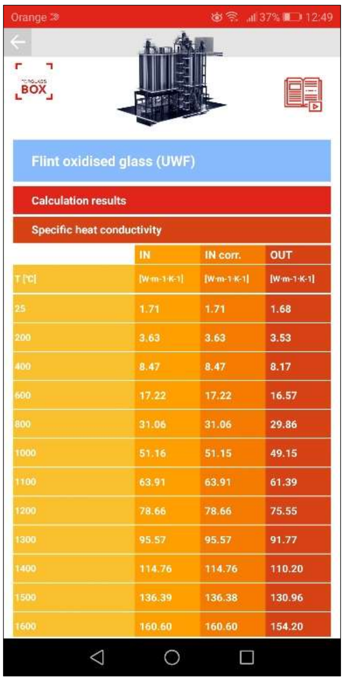
Flint oxidised glass (UWF)

Calculation results

Specific heat

	IN	IN corr.	OUT
T [°C]	c_p [J·kg^{-1}·K^{-1}]	c_p [J·kg^{-1}·K^{-1}]	c_p [J·kg^{-1}·K^{-1}]
25	786.45	786.40	786.00
200	1033.53	1033.47	1032.95
400	1182.87	1182.81	1182.22
600	1268.09	1268.02	1267.39
800	1321.26	1321.19	1320.53
1000	1356.64	1356.58	1355.90
1100	1370.05	1369.98	1369.29
1200	1381.37	1381.31	1380.62
1300	1391.03	1390.97	1390.27
1400	1399.34	1399.27	1398.57
1500	1406.53	1406.46	1405.75
1600	1412.79	1412.72	1412.02

Step 24. **Screen 21** shows the calculated values of specific heat at temperatures of: 25, 200, 400, 600, 800, 1000, 1100, 1200, 1300, 1400, 1500 and 1600°C



Flint oxidised glass (UWF)

Calculation results

Specific heat conductivity

	IN	IN corr.	OUT
T [°C]	[W·m-1·K-1]	[W·m-1·K-1]	[W·m-1·K-1]
25	1.71	1.71	1.68
200	3.63	3.63	3.53
400	8.47	8.47	8.17
600	17.22	17.22	16.57
800	31.06	31.06	29.86
1000	51.16	51.15	49.15
1100	63.91	63.91	61.39
1200	78.66	78.66	75.55
1300	95.57	95.57	91.77
1400	114.76	114.76	110.20
1500	136.39	136.38	130.96
1600	160.60	160.60	154.20

Step 25. **Screen 22** shows the calculated values of specific heat conductivity at temperatures of: 25, 200, 400, 600, 800, 1000, 1100, 1200, 1300, 1400, 1500 and 1600°C