GLASS ENGINEERING ON DEMAND

IMPROVING PRODUCTIVITY FOR GLASS PRODUCERS

User Manual

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1 COPYRIGHT AND EXCLUSION OF LIABILITY

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3 INTRODUCTION

Glass Engineering on demand. Improving productivity for glass producers.

There is hardly any other material that is more versatile that glass. The production processes in the glass industry are correspondingly complex. In addition, energy costs are rising, environmental protection requirements are getting tougher and competitive pressure is increasing. If glass producers wish to make their processes more efficient and more economical, transparency is required, day after day. For this reason, Linde Gas and OGIS GmbH have developed the world's first calculation tool to support you in the analysis, planning and monitoring of all process parameters online.

Online Glass-Engineering (called OGE in the following) groups together all the necessary, cross-technology engineering tools in one common engineering suite. Continuous data management and the use of "wizards" (to assist data entry) in all the individual models simplify operation and reduce the level of work required.

Any time, any place

Controlling all the parameters in the many different production processes in the best possible way requires intelligent software support. But instead of investing in a separate solution which costs time and effort to maintain, glass producers have now turned to an internet-based calculation tool that provides individual key data at any time and allows extremely complex analyses to be performed: With Glass Engineering, you have all the necessary functions on hand and your glass, raw material and batch data at your fingertips at all times. This helps you support your overall knowledge management, from heating technology to evaluation of operating data.

Your entries and requests are protected by the latest security data transfer using SSL encryption and are available to you 24 hours a day. You can use a glass-specific database to help your experts make reliable decisions.

There is potential for improvement in every glass production unit.

You just need to know where.

Making working procedures easier, creating more homogeneous melting conditions, saving energy – or taking individual customers' requirements flexibly into account in the production process: every step forward is based on making improvements. But decision-makers demand certainty. When will your investments start to pay off? What parameters can be used to define success? What will be the medium-terms effects of the changeover from oil to gas?

With Glass Engineering, glass manufacturers gain the transparency they need to optimise their processes consistently. Send an e-mail to engineering@glassglobal.com and we'll send you your access data and detailed user information immediately.

4 ONLINE GLASS ENGINEERING

4.1 Online Tool

OGE is an online software program. That means that you can only use the software online, via the internet and that it runs under your preferred browser (Microsoft® Internet Explorer or Netscape Navigator). The use of wizards makes day-to-day work much easier, since they guide users through the most frequent and most time-consuming processes.

4.2 Security

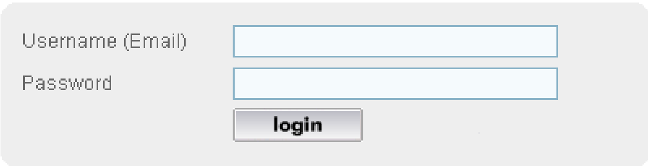


Figure 1 - Login boxes

All the pages of OGE are password-protected. If you call up a page without registering first, you will automatically be taken to the login area. To allow you to use all the modules, you must log in here first using your access data (e-mail address and password). The password is case-sensitive, i.e. you must enter it correctly in terms of upper and lower case. As you are entering the password, you will only see asterisks on screen, rather than the characters typed by you.

4.3 Program structure

The program is subdivided into individual modules which are either used for pure data management (e.g. gases, oils, refractory material, etc.) or for carrying out complex calculations (analysis, balances). In addition, there are higher-level modules such as Setup, Settings, Supplier Management and Employee Management.

Module	Description
Furnace	Management of all furnace data. Daily reports. Gas and oil database. Management of refractory materials. Calculation of thermal flow in a wall.
Raw material	Management of all raw materials used and chemical analyses. Processing of silo data and daily deliveries.
Batch	Management of all batch data and processing of evaporation rates.
Glass	Management of all glass data (chemical analyses) and processing of target glasses..
Energy balance	Preparation of energy balances including comparison of individual balances. Conversion to oxygen furnace, use of boosters.
Suppliers	Management of all supplier addresses. (Optional: complete correspondence tool, billing,...).
Setup	Setting of various basic parameters, personnel management (access authorisations), update function (USB variant)

Table 1 - Overview of all modules

4.4 General screen structure

The OGE main window which you access after logging in is based on the same structure irrespective of the module you have just called up. Figure 2 shows this overview window, using the example of furnace data.

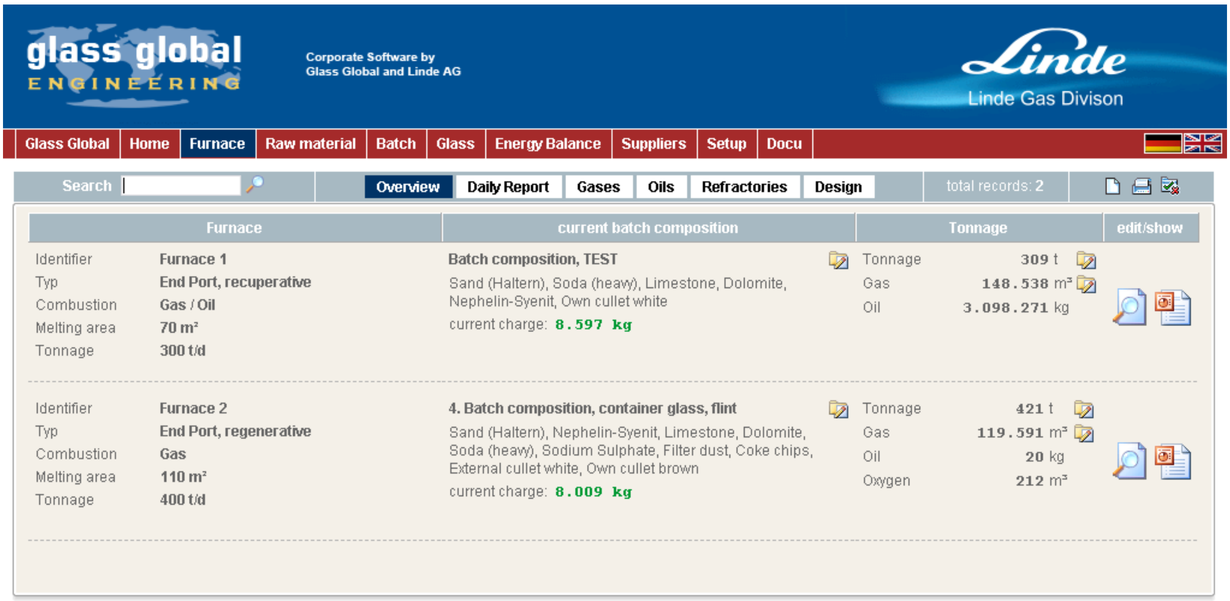


Figure 2 – General screen structure (showing start page, furnace overview)

All the overview pages are built up in the same way. The red menu bar is the central control element which can be used to call up all the main modules in the software program. To call up the individual modules, click with the mouse on the corresponding area in the red main menu bar.

Apart from a few exceptions, the presentation of the data is structured in the same way in all modules. Every module contains a general overview showing the most important data from the module in question.

The blue area underneath contains a search box on the left which will carry out a search in the current module. In the figure above (furnace overview), you can search for particular furnace data, for example. The results are displayed in table form.

In the middle of the blue bar, you will find more sub-menu items, depending on the module. In Figure 2 here, for example, we have the menu items Daily Report (collation of all current furnace and production data for that day), Gases (chemical analysis of the gases used), Oils (chemical analysis of the oils used), Refractories (management of refractory materials used) and Design (program for calculating the transport of heat in the furnace walls). The menu item "Overview" takes you back to the main overview for the module in question.

4.5 Use of icons

To make work easier for you, icons are used throughout the software. Every icon represents a particular function (e.g. open wizard, print data, ...). The following tables describes all the symbols used in the program.

	This symbol is the wizard symbol. If you click on it, the entry assistant for processing the data set in question will open. You will find this symbol on the right-hand side in the general overview, next to the relevant data set.
	Clicking on this symbol opens the detailed view of the current data set.
	You will find this symbol in many different places throughout the system. Clicking on it will open a wizard for direct processing of a data set. Which wizard opens depends on the module you have just called up. In Figure 2, for example, you will find this symbol next to the details of a batch formula. Clicking on this symbol will take you straight to the current overview of the batch formula.
	If you click on this symbol, a new data set is created in the module that is currently open. The wizard opens and you can edit the data set directly.
	Clicking on this symbol opens a new window, showing the current table overview as a print preview.
	Clicking on this symbol will open up the wizard for the basic settings.
	If you click on this symbol, the Online Help facility will open as a pdf file in the relevant language (German, English). You can save the file to your PC or print it out as a manual.

Table 2 - Overview of symbols used

4.6 Offline version

For users who have to have their data ready to hand all the time or who have a slower internet connection, an offline version has been developed which is available on a standard USB stick. This version has the same range of functions as the online version. In addition, it also contains a number of update functions (e.g. if the complex algorithms are changed).

For further details, please contact OGIS GmbH at engineering@glassglobal.com or by telephone on +49-211-280733-0.

5 Energy Balance

5.1 Overview

In this module, you can prepare a range of energy balances. These provide a comparison of all the energy flows supplied and removed in a thermotechnical process. The thermal balance allows conclusions to be drawn regarding energy efficiency and the nature and scale of energy losses. The more detailed the recording of the balance parameters, the easier it is to find starting points for technical and technological improvements. One of the major features of the thermal balance of melting furnaces is the link between the upper furnace and heat recovery.

For detecting energy losses in a melting furnace, this module is also able to compare various parameters for a bath with the current setup. In this way, for example, the effect of using a booster can be calculated beforehand before the furnace is rebuilt at considerable expense.

5.1.1 Functions of the overview page

You can access the Energy Balance module by clicking on the item "Energy Balance" in the red menu bar. This will take you automatically to the overview of all the balances prepared to date.

Search box		
Menu icons (top right)		If you click on this symbol, a **new data set** is created in the module that is currently open. The wizard opens and you can edit the data set directly.
		Clicking on this symbol opens a new window, showing the current table overview as a print preview.
Column: Designation	Designation of energy balance (can be freely selected), date of last edit and number of variants (only displayed if variants have been created for the current balance)	
Column: Production	Current production data from the energy balance.	
Column: Energies	Already calculated values of current balance (depending on the result, only fields with a usable result will be displayed)	
Column: Efficiency	Shows the efficiency for combustion, air preheating and total efficiency.	

5.2 Wizard - data entry

As already described above, all data changes are made using a wizard. To edit a data set, click with the mouse on the wizard symbol ( ) on the outside right of the corresponding line. The following describes the individual pages and the entry fields in the wizard for editing an energy balance:

5.2.1 Step 1: Description

Entry field	Description
Select data set	If you want to edit a particular data set, select the corresponding entry from the pulldown menu in the first line.
Select variant	If you have already created variants for an energy balance, you can select these from the pulldown menu Variant.
Designation	Give the current data set a name and a brief description. The designation is used to find it faster in the general overview.
Date	This is where you can enter the date on which the energy balance was prepared.
Description	You can use this field to enter additional comments which are taken into account if you carry out a search.

5.2.2 Step 2: Basic data

Entry field	Description

Melt surface	Enter the total melt surface of the furnace for which the energy balance is to be prepared. The melt surface of a melting furnace in m² is necessary to estimate the wall losses and to calculate the specific furnace load.
Melting capacity	Enter your daily melting capacity in tonnes per day.
Amount of cullet	-
Temperature of combustion air	Temperature of preheated combustion air on entry into furnace (or ambient temperature in the case of oxygen furnaces).
Exhaust gas temperature	Enter the temperature of the exhaust gas on exit from the furnace (measurement point generally at top of chamber)
Glass temperature, aperture	-
Air (main firing)	Select the air composition of the main firing here. You can carry out the corresponding gas analysis in the Furnace/Gas module. If you click on the small wizard symbol on the left, next to the pulldown menu, you can edit the gas analysis in a separate wizard window.
Infiltrated air	This is where you can select the air composition of the infiltrated air. You can carry out the corresponding gas analysis in the Furnace/Gas module. If you click on the small wizard symbol on the left, next to the pulldown menu, you can edit the gas analysis in a separate wizard window.
Oxygen content in exhaust gas, after furnace	The oxygen content is generally measured via lambda probes in the top of the chamber. This value has a crucial influence on the calculation of the energy balance and should be given very precisely.
Lambda combustion air	-

5.2.3 Step 3: Firing

Entry field	Description
Firing	In this menu, you can select the type of furnace firing: either gas or oil or a gas/oil mix. Depending on your selection, you will be provided with different entry fields for gas, oil or both.
Gas	Select the corresponding gas composition from your analysis database here. If you click on the small wizard symbol on the left, next to the pulldown menu, you can edit the analysis in a separate wizard window.
Lower calorific value, gas	If you have not chosen a gas from the list, please enter the calorific value of your gas in this field. If you have chosen a gas from the list, the calorific value is calculated automatically and used for the energy balance.
Gas consumption per day	Enter the gas consumption per day in Nm^3 here.
Proportion of gas	If you are working with gas and oil, enter the proportion of gas as a percentage here. The amount of gaseous fuels as a proportion of the total fuel content is normally calculated by offsetting the gas and oil quantities in calorific terms. In a prediction, this value can be set freely, and the gas and oil quantities will then be calculated accordingly.
Oil	Select the corresponding oil composition from your analysis database. If you click on the small wizard symbol on the left, next to the pulldown menu, you can edit the analysis in a separate wizard window.
Lower calorific value, oil	If you have not chosen an oil from the list, please enter the calorific value of your oil in this field. If you have chosen an oil from the list, the calorific value is calculated automatically and used for the energy balance.
Oil consumption per day	Enter the oil consumption per day in kg here.
SEH	If you use supplementary electric heating (SEH), please enter the consumption in kWh/day here.

5.2.4 Step 4: Oxy Boosting

Entry field	Description
Additional burner	Please select, from the menu, whether you want to use Oxy-Boosting (select: Yes) or not (select: No). Note: During the furnace life, the capacity of a glass furnace decreases. To balance out the loss of capacity, or to increase the capacity, you can use "Oxyboosting". If, for example, you have to repair your glass furnace and want to keep production utilisation stable or if you want to reduce emissions during your combustion process, you can select the Oxyboosting solutions developed by Linde Gas.
(the following fields will only appear if you have selected YES.	
Air	Select the corresponding composition of the air for the booster from your analysis database. If you click on the small wizard symbol on the left, next to the pulldown menu, you can edit the analysis in a separate wizard window.
(the following fields will only appear if you have selected an air analysis)	
Costs of air	This is where you can enter the costs of the combustion air, as an option. The energy balance will incorporate this value into the general overview.
Lambda	Enter the lambda value of the air here.
Gas consumption	If you are using a gas booster, please enter the gas consumption in Nm^3 per day here.
Oil consumption	If you are using an oil booster, please enter the oil consumption in kg per day here.

5.2.5 Step 5: Glass

Entry field	Description
Glass	You can enter the glass analysis currently in use from your database. If you click on the small wizard symbol on the left, next to the pulldown menu, you can edit the glass analysis in a separate wizard window. If you do not select any glass at this point, the calculation will be carried out with a glass from your basic settings (soda-lime glass, lead glass, appliance glass)
Proportion of water in cullet	-
Proportion of water in batch	-
Melt losses of batch without H2O	-

5.2.6 Step 6: Temperatures

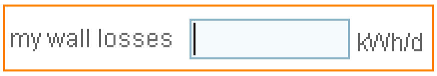
Entry field	Description
Temperature of combustion air (additional burner)	Enter the intake temperature of the combustion air for the additional burner here.
Batch temperature at feeder	Enter the temperature of the batch at the feeder here (standard value 20°C).
Cullet temperature	Enter the temperature of the cullet at the feeder here (standard value 20°C). This parameter is very suitable for checking the benefits of cullet preheating back at the planning stage.
Temperature of combustion gas	Enter the temperature of the combustion gas here (standard value 20°C).
Temperature of oil	Enter the temperature of the oil (oil burner) here (standard value 20°C).

5.2.7 Step 7: Costs

In order to give you an idea of the costs involved in an energy balance, please enter all costs for your energy media (where available). Entering the costs is not relevant for the technical results of a balance, but it is crucial for revealing potentials for savings.

5.2.8 Step 8: Wall losses

This is the last entry screen before the actual calculation of the energy balance. If you know the wall losses for your melting furnace, you can enter this value in the field.



Determining the wall losses depends mainly on the melt surface of your furnace and the exhaust gas temperatures. On the basis of these data, this page will prepare an initial rough estimate of the wall losses.

To start the calculation, click on the *Prepare energy balance* on the bottom right. As soon as you have started the calculation, you will see a progress bar in the next window. Depending on the nature and scope of the energy balance, the calculation may take a few seconds.

5.2.9 Step 9: Completion

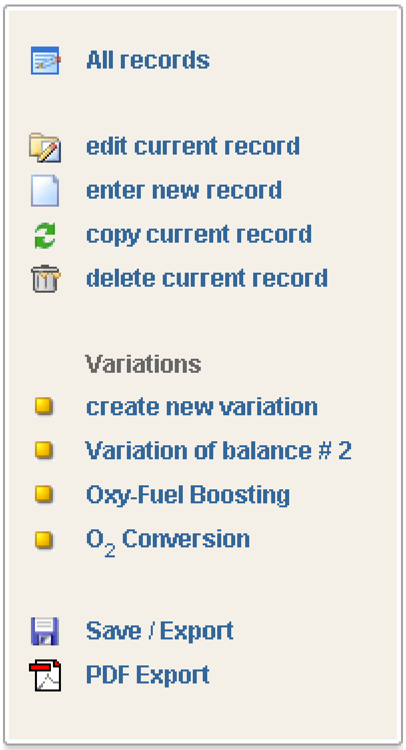
As soon as the calculation has been completed, you will move to the final window which offers you various options for using the results. Click on one of the following entries:

Display energy balance in overview	The wizard is closed and the program changes to the detailed view of the energy balance.
Print energy balance	The wizard is opened and a new window is opened showing the print view of the current balance.
Revise energy balance (back to entry point 1)	By selecting this, you can go back to the first page of the wizard.

To start the selection click on the *Run selection* button on the bottom right.

5.3 Detailed view

The detailed view presents all the data on the current module in a clearly structured form.



All records	Changes back to the general overview of the energy balances.
Edit current record	Opens the wizard for editing data described in 5.2.
Enter new record	Creates a new data set and opens the wizard for editing data.
Copy current record	Copies the current data set and adds the word "Copy" to the heading.
Delete current record	Deletes the current data set. If you have stated, in Setup, that every deletion must be confirmed, then you will be asked if you are sure that you want to continue; you should answer this with Yes (delete) or No (cancel).
Create new variation	Creates a variant of the original balance data. For more about this, see Sect. 5.3.2.
Variation of balance x	Creates a variant from an existing variant. This menu item only appears if you have already created one variant. For more about this, see Section 5.3.2.
Oxy-Fuel Boosting	Opens the wizard to calculate the use of Oxy Boosters. For more about this, see Section 5.3.3.
O2 Conversion	Opens the wizard for conversion of a Setup to an oxygen furnace (AOF). For more about this, see Section 5.3.4
Save/Export	Opens an export window in which you can define the export format and save the backup file.

Table 3 – Menu items: Energy balance

5.3.1 Results window

You will find the results of the energy balance on the right-hand side of the window. To maintain a clear overview, only the most important fields will be shown as standard. The display is then classed as "compact". If you select "all" for the display, all the available fields and results will be displayed.

If you want to call up a particular balance that has already been prepared, select it from the yellow pulldown menu (Selection).

The results table is subdivided into various column groups. On the right-hand side you will find the properties that have been calculated or entered by you. To improve the clarity of the display, the properties are divided into groups. On the left next to the field name, you will find a green and a blue rectangle, for marking.

The green rectangle ( ) marks the values that were entered by you via the wizard. The blue rectangle ( ) marks the values that were calculated by the software.

The column Original shows the values for the first energy balance. Further variants can then be created on the basis of this result. The top line contains more symbols for the original balance:

 If you click on this symbol, the wizard opens and takes you to the first entry page for direct editing of the current data set.

 If you click on this symbol, a new window opens for printing out the current data set.

 If you click on this symbol, a new window opens and shows you the most important parameters in the form of a bar chart.

If you have already prepared variants, these will be displayed in more columns to the right of the original balance. The first line contains a similar symbol bar. The functions are identical to those in the original symbol list, except that when opening the wizard, you can display and edit the variant in question rather than the original.

In addition, you will find the  symbol, which you can use to delete the current variant. If you have stated in Setup that every deletion must be confirmed, then you will be asked if you are sure that you want to continue; you should answer this with Yes (delete) or No (cancel).

5.3.2 Variants

This function can be used to compare any number of energy balances. This provides you with a direct overview of what effect the individual changes are having. To create variants, you must first determine the wall losses. Then use the tabs to move to the entry pages and change the entry parameters.

To compare all the values in a table with the original values, click on the left button "calculate". If you want to have the results of the comparison of the individual energy balances displayed, click on the Text link below. The data will be displayed in a new window, for greater clarity.

5.3.3 Oxy-Fuel Boosting

This program item is one of the most interesting in the calculation of energy balances. On the basis of the original balance (original data), the wizard creates a new variant with the simulated incorporation of additional oxygen burners (Oxy-Boosting). You can access this wizard via the menu item "Oxy-Fuel Boosting" in the left-hand menu bar. Figure 3 shows the opened wizard:

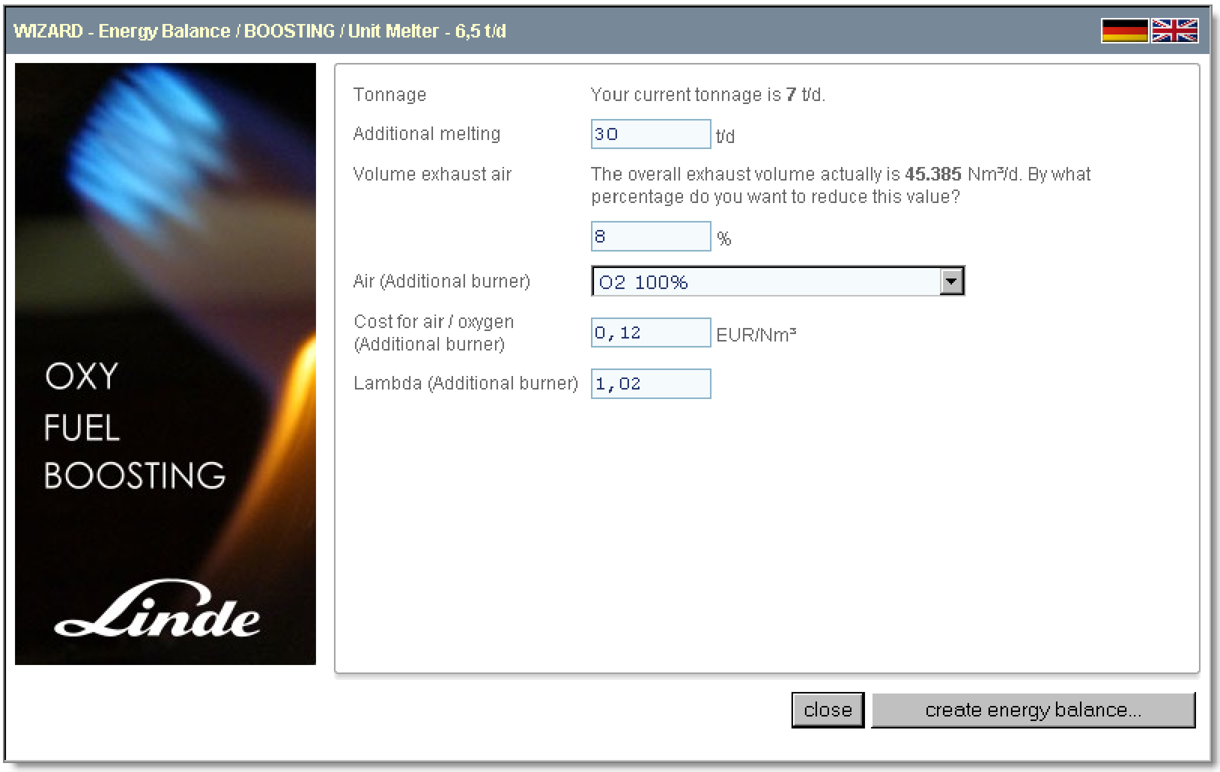


Figure 3 – Wizard for preparing a balance with Oxy-Boosting

You now have a number of additional options before the calculation. In the example shown, the furnace is operated with a tonnage of 7 t/d. In the next box, you can now increase the tonnage by x tonnes/day. In the *Exhaust gas volume* field, you can enter the percentage by which you want to lower the total exhaust gas volume. In the field *Air (additional burner)*, you can enter the medium you want to use for your burner (generally pure oxygen).

Once you have completed your entries, click on the bottom right on "Prepare energy balance..." to start the calculation. In the next window, you will see a progress bar, which will run until the calculations have finished. After completion, the window closes automatically and you will be taken to the detailed view.

Note: Since the algorithm for the Oxy-Boosting calculation is very complex, this process may take up to a minute.

5.3.4 O2 Conversion

This function creates a new balance variant. In this variant, the firing of your furnace will be converted from gas/oil to pure oxygen. In this process, the parameters exhaust gas temperature, temperature of air preheating, type of combustion air, and lambda value and wall losses will be automatically adjusted. Figure 4 shows the opened wizard:

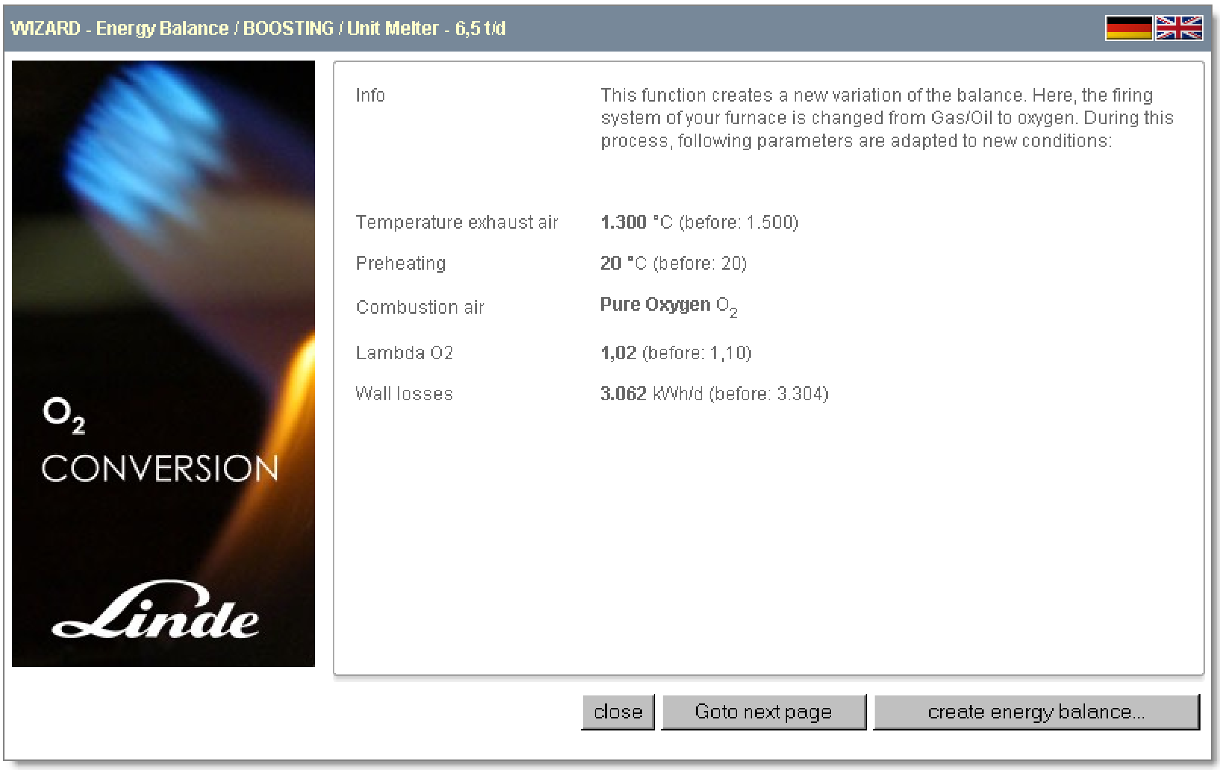


Figure 4 – Wizard for preparing a balance with 100% oxygen

To start the calculation, click on the bottom right on "Prepare energy balance...". In the next window, you will see a progress bar, which will run until the calculations have finished. After completion, the window closes automatically and you will be taken to the detailed view.

6 Raw Material

6.1 Overview

In this module, you can manage all your raw materials and chemical analyses. In the middle of the blue bar, you will see other sub-menu items: Silo (management of individual silos), Deliveries (management of raw material deliveries). The menu item "Overview" will take you back to the main overview of all raw materials.

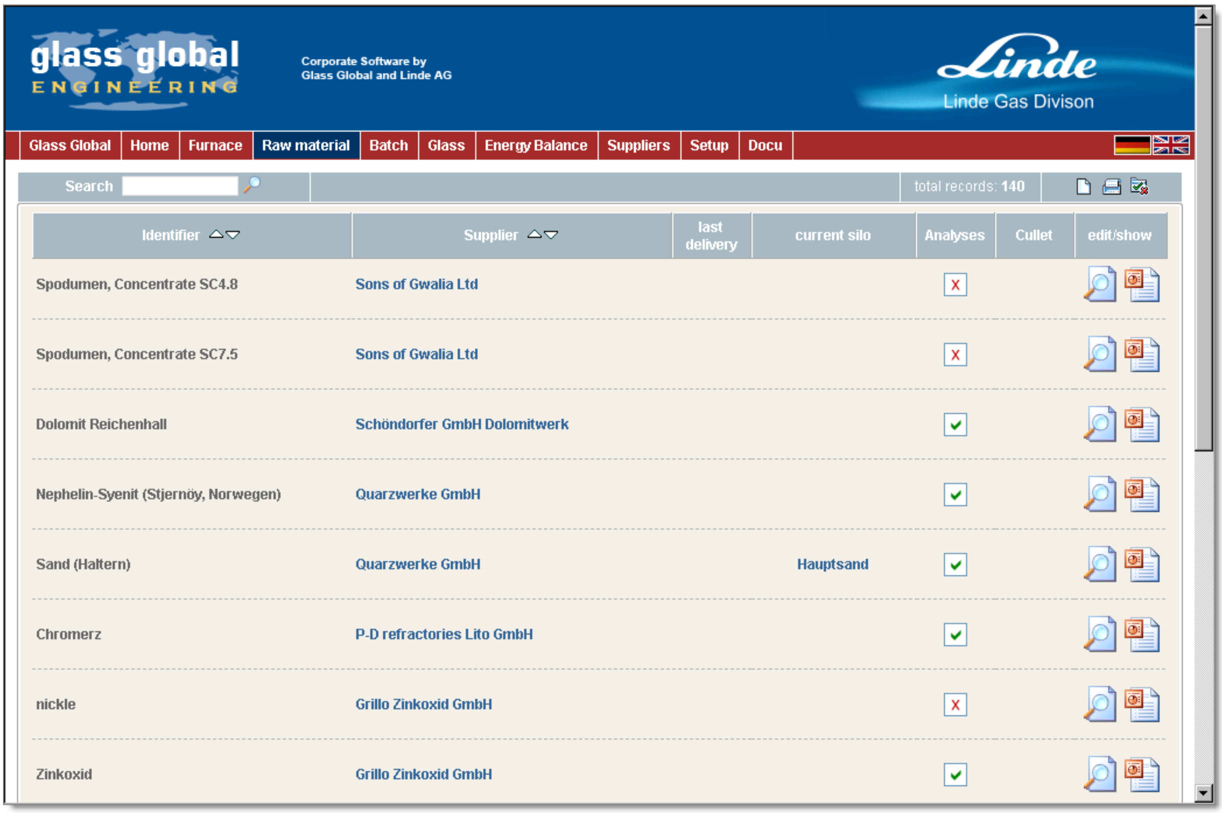


Figure 5 - Overview of batch formula

6.1.1 Functions of the overview page

You can access the Raw Materials module by selecting the item "Raw Materials" with the mouse in the red menu bar. This will then take you automatically to the overview of all raw materials/analyses prepared so far.

Column: Designation	Designation of raw material (can be freely selected)
Column: Supplier	The Supplier column is linked with the relevant supplier for this raw material. The address can be reached directly via the link.
Column: Current silo	This column shows the silo in which the raw material is currently stored. The silo data can be reached directly via the link.
Column: Cullet	This column indicates whether this raw material is cullet and what type. A distinction is made between the following entries:

E Own cullet F External cullet M Mixed cullet

6.2 Wizard - data entry

To edit an existing raw material, click on the wizard symbol () on the outside right of the corresponding line. The following describes the individual pages and the wizard entry fields for editing a raw material:

6.2.1 Step 1: Description

Entry field	Description
Select data set	If you want to edit a particular data set, select the corresponding entry from the pulldown menu in the first line.
Designation	Provide a name and brief description for the current data set. This designation will help you to find it more quickly in the general overview.
Sand	You can define here whether the current raw material is sand. To do this, select the entry Yes or No.
Type of cullet	If the current raw material is cullet, select the type of cullet here (own, external or mixed cullet). With "normal" raw materials, leave this field at the standard entry: *no cullet*
Status	This is where you can enter the date on which the raw material was entered.
Supplier	Select the raw material supplier. The selection list contains all the addresses that you have entered in the menu item *Suppliers*. If you click on the small wizard symbol on the left, next to the pulldown menu, you can edit the address in a separate wizard window.
Description	You can use this field to enter additional comments which are taken into account if you carry out a search.

6.2.2 Step 2: Costs / Redox

Entry field	Description
Raw material costs	Enter the raw material price per tonne here. You can change the currency display in the Setup menu.
Tonnage / truck	Enter the tonnage of a truck delivery here. This can then be used to calculate how many truck deliveries are required and/or at what intervals deliveries should be made.
Bulk density	Enter the bulk density of the raw material in kg/dm^3 here. Definition: *The bulk density is the ratio of the mass of a granular substance (e.g. sand) to its volume including the pores within the grains and the cavities between the grains (intra-aggregate pores).*
Scale tolerance	-
Redox figure	Enter the redox figure of the raw material here.
Carbon figure	Enter the carbon figure of the raw material here.
COD value	Enter the COD value of the raw material here. Definition: *COD (chemical oxygen demand) is the quantity or volume-related mass of oxygen that is needed for the compete oxidation of organic (greater part) and inorganic (minimal significance) substances.*

A description of the redox calculation is given in 6.4.

6.2.3 Step 3: Chemical analysis

In this step, you record the chemical analysis of the current raw material. The overview shows you the first 6 oxides and the percentage content. The figure here shows the screen display using the example of the raw material analysis for dolomite. this table shows ALL the analyses that you have created for this raw material.

Date

Date	SiO2	Na2O	K2O	CaO	MgO	Al2O3	
01.04.2005	0,0500	0,0300	0,0100	30,2000	21,7000	0,0300	
23.03.2005	0,2340	0,0000	0,0000	31,0620	21,9730	0,0554	
05.03.2005	0,2220	0,0000	0,0000	31,0420	21,9926	0,0526	
12.02.2005	0,2050	0,0000	0,0000	31,0225	22,0153	0,0513	
02.02.2005	0,1967	0,0000	0,0000	30,9800	22,0193	0,0510	

Figure 6 - Example of raw material analysis (dolomite)

Edit raw material analysis

To edit a single entry, click on the symbol. Because the chemical analysis of a single raw material can be very extensive, the analysis is edited in a separate window.

All the entries (designation, status, costs, carbon figure, redox figure, COD value) that you can carry out in the first step of the wizard relate to the current analysis, in contrast to the entries described in 6.2.1.

Because of the high number of oxides (up to 65 oxides can be listed), entry is in three steps. Firstly, the most important oxides are displayed. If you click on the button "Save and continue to next page", you will move to the next windows in the wizard step by step.

Once you have ended all the entries, click on "Close" to close the current wizard. The wizard for the raw material analysis will still be in the background.

If you want to end your analysis entry, click on the *Goto to next page* button on the bottom right.

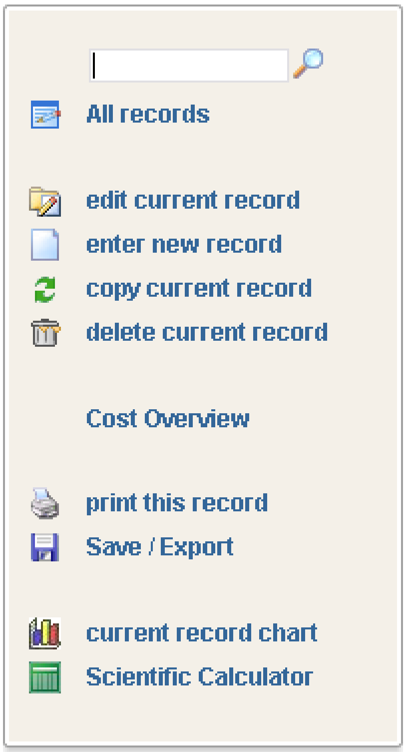
6.2.4 Step 4: Completion

As soon as you have finished the entries, you will move to the final window which offers you various options for using the results. Click on one of the following entries:

Display result of raw material analysis in the overview	The wizard is closed and the program changes to the detailed view of raw material analysis.
Print current data set	The wizard is opened and a new window is opened showing the print view of the current raw material analysis.
Revise raw material (back to entry point 1)	By selecting this, you can go back to the first page of the wizard.

To start the selection, click on the button on the bottom right, *Execute selection*.

6.3 Detailed view



All records	Changes back to the general overview of the Raw material analyses.
Edit current record	Opens the wizard described in 6.2 for editing data.
Enter new record	Creates a new data set and opens the wizard for editing data.
Copy current record	Copies the current data set and adds the word "Copy" to the heading.
Delete current record	Deletes the current data set. If you have stated, in Setup, that every deletion must be confirmed, then you will be asked if you are sure that you want to continue; you should answer this with Yes (delete) or No (cancel).
Cost overview	Opens a separate window and shows you an overview of the raw material, the price per tonne and the latest status.
Print this record	Opens a separate window showing the glass analysis with the most important parameters for printing.
Save/Export	Opens an export window in which you can define the export format and save the backup file.
Scientific Calculator	Opens a separate window and provides you with a small pocket calculator with all the necessary functions.

Table 4 – Menu items: Raw material analyses

6.3.1 Results window

You will find the results of the raw material analyses on the right-hand side of the window. The upper part basically shows the values that you entered in Step 1 of the wizard. If you want to call up a particular raw material analysis that you have already carried out, select this from the yellow pulldown menu (Select).

You will then access the area "Raw material analyses". On the left, you will see the date of the most recent analysis. If you click on the test link, the wizard is opened and a new analysis created for the current raw material. The right-hand side shows the chemical composition of the last analysis. To edit this directly, click on the symbol (on the right above it).

6.4 Sulphate refining

If sulphates and sulphides are used, the refining gases SO2 and SO3 are created, which dissolve in the glass. The solubility of SO42- is directly proportional to the O2 partial pressure and that of S2- is in inverse proportion to it, i.e. for the sulphur solubility and the nature of the dissolved sulphur, the redox status of the glass is decisive.

The O2 partial pressure not only influences the states of the sulphur but also the oxidation states of all polyvalent ions in the glass, such as Fe, Mn and Cr.

If one therefore determines the ratio of a particular oxidation state to the total content of the corresponding element, one also has a measurement for the O2 partial pressure or the redox state of the glass in question.

It has become normal to plot the redox state of a batch in a diagram against the total sulphur content (calculated as SO3) of the glass.

However, it should be borne in mind that the solubility of the various sulphur compounds and the oxygen is still also dependent on the composition of the glass and the temperature.

This type of plotting has the disadvantage that a glass first has to be melted and the corresponding sulphur or Fe content determined before a conclusion can be drawn as to what happened during the melting.

A redox potential should clearly be assigned to the individual raw materials. Today, the use of the following variants is usual:

1) Carbon numbers
2) Redox numbers
3) COD values

6.5 Carbon figure, redox figure and COD value

The reference basis for these calculations is carbon. The raw material quantities present in the batch are multiplied by the corresponding factor and the individual values are added together. The values relate in each case to 1 kg of the raw material in question and are related in their totality to a batch with 2000 kg sand. When entering the raw materials (see raw material analysis), it is therefore important to state whether a raw material is "sand"; otherwise, the calculation cannot be carried out.

7 BATCH

7.1 Overview

In this module, you can manage all your batch formulae. The raw materials required for glass production are weighed out in certain quantities in accordance with the glass composition and mixed with each other. A batch is therefore understood to be the weighed out ratio of the raw material quantities in the mixed state that is necessary for the production of a glass with a particular composition.

The term batch formula is understood to mean the defined weight of a particular quantity of glass containing the individual components calculated for a previously defined total quantity.

This module offers 2 very interesting calculation possibilities:

1. You can convert an existing batch to any value you require (the cullet content remains constant).
2. You can have an existing batch formula automatically converted in such a way that the resultant glass batch precisely (taking tolerances into account) meets your requirements (Desired Glass).

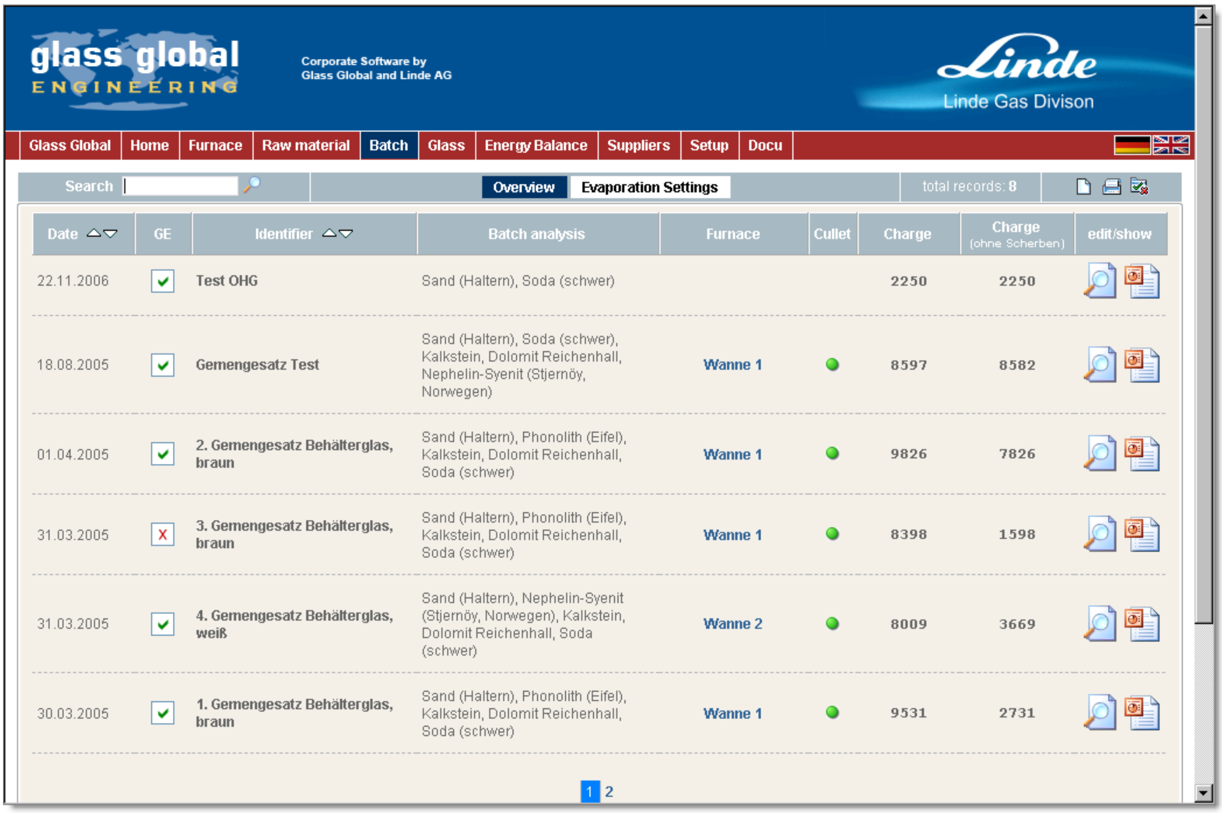


Figure 7 - Batch formula overview

The blue area underneath the main menu bar contains, on the left-hand side, a search box for searching in the current module. There are other sub-menu items in the middle of the blue bar, depending on the module.

Evaporation settings: Setting the volatile components for use in batch formulae. The menu items "Overview" will take you back to the main overview for all glass formulae.

7.1.1 Functions of the overview page

You can access the Batch module by clicking on "Batch" in the red menu bar. This will automatically take you into the overview of all batch formulae already created.

Search box	
Menu icons (top right)	If you click on this symbol, a **new data set** is created in the module that is currently open. The wizard opens and you can directly edit the data set.
	If you click on this symbol, a new window opens showing the print preview of the current table overview.
Column: GP	The column **GP** shows whether the associated glass properties have been calculated for the current batch formula or not.
Column: Designation	Designation of batch formulae (can be freely selected)
Column: Batch formula analysis	Current composition of batch formulae. Only the first 10 raw materials will be displayed, for greater clarity.
Column: Furnace	The furnace column is linked with the relevant melting furnace for which this batch formula was prepared and can be directly accessed via the link.
Column: Cullet	Shows whether the current batch formula also contains cullet as a raw material. If it does, this is indicated by a green dot.
Column: Charge	Gives the value of the current charge. This is made up of the complete individual weighed out quantities.
Column: Charge (without cullet)	Gives the value of the current charge excluding the cullet weight.

7.2 Wizard - data entry

To edit an existing batch formula, click on the wizard symbol () on the outside right in the relevant line. The following describes the individual pages and the entry fields of the wizard for editing a batch formulae:

7.2.1 Step 1: Description

Entry field	Description
Select data set	If you want to edit a particular data set, select the corresponding entry from the pulldown menu in the first line.
Designation	Allocate a name and brief description for the current data set. The designation will help you to find it faster in the general overview.
Date	This is where you can enter the date on which the batch formula was prepared.
Furnace	Select the furnace for which you want to compile the batch formula. The selection list contains all the furnaces that you entered under the menu item *Furnace*.
Evaporation	Select the evaporation which is to be included in the calculation of the batch formulae. The selection list contains all the evaporation rates that you entered under the menu item *Furnace/ Evaporation*.
Desired Glass	In the *Desired Glass* field, select an existing glass analysis on the basis of which the batch formula is to be modified. This means that the batch formula will be calculated in such a way that the glass properties that you specified for this Desired Glass will be achieved in the melting process. You can also define tolerances in the module "Desired Glass".
Description	You can use this field to enter additional comments which are taken into account if you carry out a search.

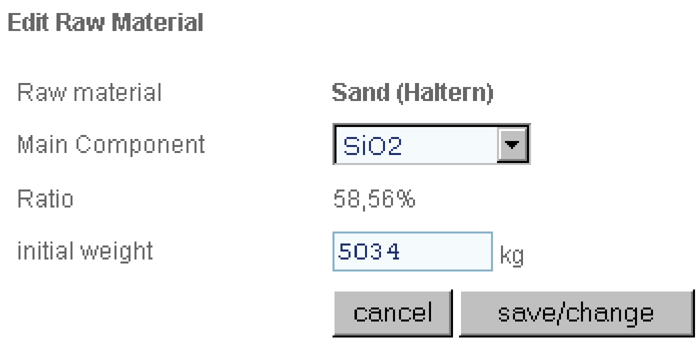
7.2.2 Step 2: Compile batch formula

In this Step, you compile the actual batch formula, i.e. you select the raw material and weighed quantity for each entry. The overview shows all the raw materials that you have used so far in the current batch formula. The proportion by weight of the total batch is automatically calculated. The figure shows the screen display using the example of a standard batch formulae.

	Raw material	Ratio	initial weight [kg]	
1	Sand (Haltern)	58,56%	5034	
2	Soda (heavy)	13,53%	1163	
3	Limestone	10,59%	910	
4	Dolomite	9,89%	850	
5	Nephelin-Syenit	7,27%	625	
6	Own cullet white	0,17%	15	

Figure 8 - Example - Batch formula

To edit an individual entry, click on the  symbol. The display changes to edit mode. If you want to delete an entry, click on the  symbol.



Raw material Shows the raw material currently being edited

Main component Since certain oxides could be contained in several raw materials, you should also give the main component (main oxide) at the same time. In the example, the main oxide for the raw material sand is SiO_2.

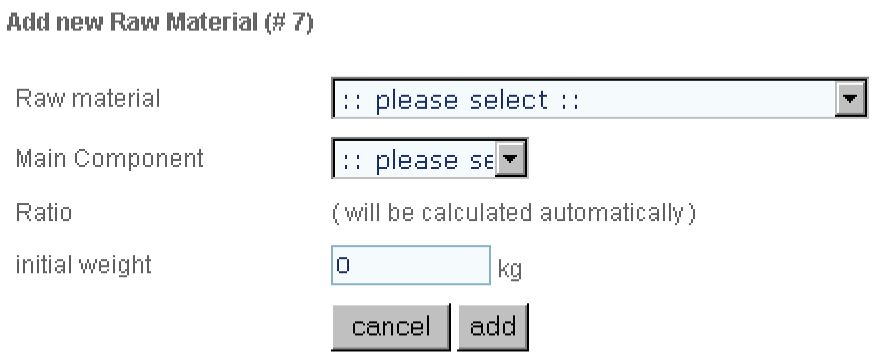
Ratio The proportion by weight of the total batch is calculated automatically.

Initial weight Enter the weighed quantity in kg for the current raw material here. In the example, 5034 kg sand are being added to the batch formula.

When you have completed your entry, click on the bottom *save/change*.

Add new raw material

To be able to add a new raw material, you have to be in the overview page (wizard Step 2). Then click on the button on the bottom left *Add raw material*. The display changes to the following screen:



Raw material	From the menu, select the raw material that you want to add to the current batch formula.
Main component	Since certain oxides could be contained in several raw materials, you should also give the main component (main oxide) at the same time.
Ratio	The proportion by weight of the total batch is calculated automatically.
Initial weight	Enter the weighed quantity in kg for the current raw material here. In the example, 5034kg sand are being added to the batch formula.

TIP
The charge weights are basically calculated automatically. You can either enter the weighed quantity for each raw material (if known), or you can enter just the total charge weight. The program then automatically calculates the corresponding weighed quantity.

To save the new raw material, click on the bottom *Add*. After saving, the program will change back to the raw materials overview and you will see the new entry.

7.2.3 Step 3: Charge weight

Once you have put together your batch formula, click on the button "*goto to next page*". You will then go to page 3 of the wizard. Here, you will be given the final information about your current batch formula and the possibility of converting the entire set to a charge.

Without deviation.

If your charge weight remains within the limits that you have entered for the current furnace, the display will stay "normal" and you will be given 2 calculation options.

☐ **Carry out calculation and do NOT take deviations into account**

With this option (standard selection), the batch formula calculation is carried out without taking deviations in the charges into account.

☐ **Carry out calculation on the basis of the Desired Glass …**

With this option, the batch formula calculation is carried out in such a way that the glass batch meets the properties specified for the Desired Glass (see 7.2.1). You can convert the entire charge to a new weight at the same time. Enter the required charge weight into the field.

With deviation

If your charge weight is outside the limits of your furnace, this is displayed in the window marked in colour. In addition to the options listed above, you also have the possibility of redefining the charge limits for your furnace.

To start the calculation, click on the bottom right on the button *start calculation*. As soon a you have started the calculation, you will see a progress bar in the next window. Depending on the nature and scope of the energy balance, the calculation may take a few seconds.

If you want to end your entry without carrying out the calculation, click on the bottom right on the button *Goto to next page*.

7.2.4 Step 4: Completion

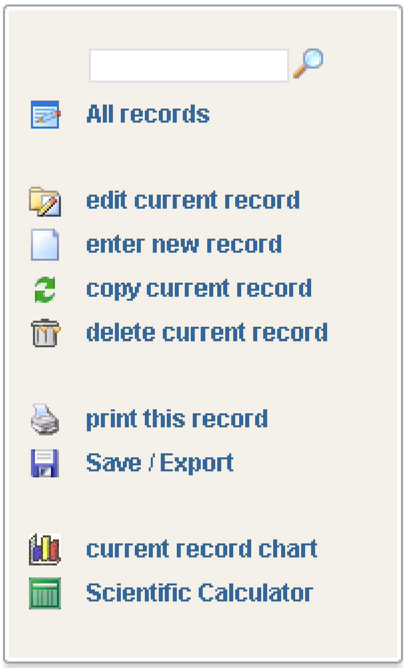
As soon as the calculation is completed, you move to the final window, where you have various options for using the result. For this, click on one of the following entries with your mouse:

Display results of analysis in the overview	The wizard is closed and the program changes to the detailed view of the batch formulae.
Print current data set	The wizard is opened and a new window is opened showing the print view of current batch formula.
Revise current analysis (back to entry point 1)	By selecting this, you can go back to the first page of the wizard.

To start the selection, click on the button on the bottom right, *Execute selection*.

7.3 Detailed view

The detailed view displays all the data for the current module in a clearly laid out form.



All records	Changes back to the general overview of the batch formulae.
Edit current record	Opens the wizard described in 5.2 for editing data.
Enter new record	Creates a new data set and opens the wizard for editing data.
Copy current record	Copies the current data set and adds the word "Copy" to the heading.
Delete current record	Deletes the current data set. If you have stated, in Setup, that every deletion must be confirmed, then you will be asked if you are sure that you want to continue; you should answer this with Yes (delete) or No (cancel).
Print this record	Opens a separate window and displays the batch formula with the most important parameters for printing.
Save/Export	Opens an export window in which you can define the export format and save the backup file.
Current record chart	
Scientific calculator	Opens a separate window and provides you with a small pocket calculator with all the necessary functions.

Table 5 – Menu items: batch formula

7.3.1 Analysis description

You will find the result of the batch formula analysis on the right-hand side of the window. In the upper part, you will find basic values that you have entered in Step 1 of the wizard. If you want to call up a particular batch formula that you have already prepared, select this from the yellow pulldown menu (selection).

Here, you will find 2 menu items for updating the data:

Update batch formula	If you click on the text link, the wizard is opened and the calculation is restarted without any query beforehand.
Calculate glass properties	If you lick on the text link, the wizard for calculating the glass properties is opened and the calculation is restarted without any query beforehand.

7.3.2 Price balance and scale tolerances

This table shows the results of the weighed quantity. The column "Weighed quantity kg" lists the calculated quantities for the current batch formula. These include the corrected total weighed quantity.

7.3.3 Target/actual comparison - glass oxides

As a rule, the calculation of a batch formulae is carried out on the basis of a Desired Glass. The table "Target/actual comparison - glass oxides" shows you whether the required oxide proportions in the Desired Glass have been achieved or not.

The column "Oxide" lists all the oxides contained in the batch formula. Alongside these are the proportions determined in percent. The column "Proportion in Desired Glass" contains the oxide proportions in the Desired Glass used and the fundamental tolerances. For the entries in the table that are marked in colour, the oxide proportions in the Desired Glass do not match the calculated values. In the case of deviations downwards (see arrow), you may need to add additional raw materials to the batch formula.

7.4 Evaporation rates

Any number of different evaporation rates can be set. In this way, particular evaporation rates can be selected for each batch formula, each furnace or each glass colour. The following oxides or compounds evaporate in solid form (dust):

SiO2, B2O3 and P2O5, Na2O, K2O, Li2O and Rb2O, TiO2, ZrO2 and SnO2, CaO, MgO, BaO, PbO, SrO, ZnO, CdO, BeO, FeO, MnO, CuO, CoO and NiO, Al2O3, Fe2O3, Cr2O3, As2O3, Sb2O3, Bi2O3 and Ga2O3, As2O5 and Sb2O5, Mn3O4

The anions evaporate in gaseous form from the melt and convert accordingly: SO3...SO2, Cl...HCl, F...HF

The exhaust gas can thus be made up of the following components: CO2, H2O, N2, NO, NO2, SO2, HCl and HF

8 GLASS

Every type of glass has the property necessary for its intended purpose, e.g. an optical glass has a particular refraction and an appliance glass has a particular chemical resistance. However, the properties of a glass, especially its viscosity, play a crucial part in production or moulding in particular.

These properties are continuously monitored in every operation, and a large quantity of equipment is required for this. On the basis of the glass composition, it is possible to calculate some of the properties of the glass.

In this module, you can manage all your glasses and chemical analyses.

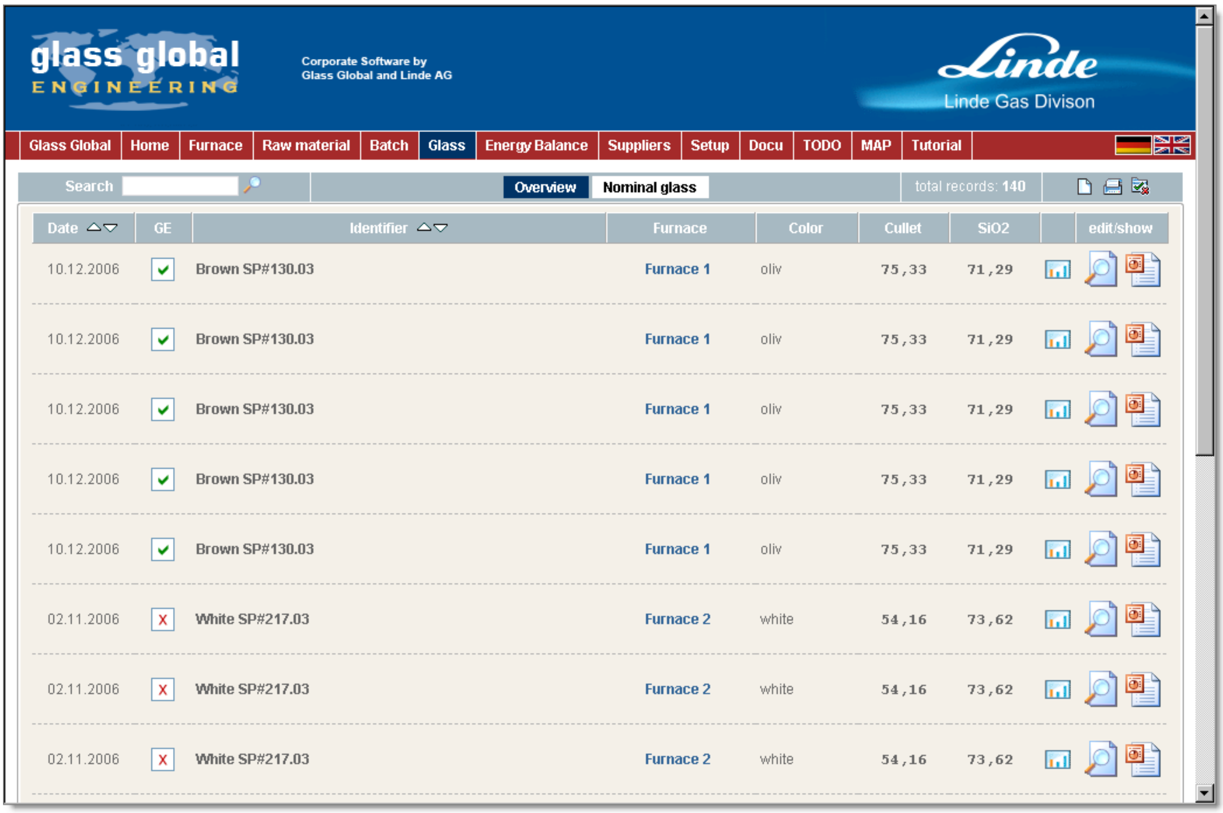


Figure 9 - Glass, general overview

The blue area underneath the main menu bar contains, on the left side, a search box for a search in the current module. There are further sub-menu items in the middle of the blue bar, depending on module.

Nominal glass: Editing of desired glasses and oxide tolerances. The menu item "Overview" takes you back to the main overview of all glasses.

8.1.1 Functions of the overview page

You can access the Glass module by clicking on "Glass" in the red menu bar. This will then take you automatically to the overview of all glasses created to date.

In the overview, the name of the glass (can be freely selected) and the creation date are displayed. The column GP shows you whether the glass properties have been calculated for the current data set or not. If the glass properties were calculated, this is indicated with a green tick. You can click on this tick directly to see the glass properties.

✔ Calculate glass properties

X Glass properties not yet calculated

The column Furnace is linked with the relevant melting furnaceand can be accessed directly via the link. If no furnace is displayed, the glass properties were calculated without being assigned to a batch formula or a furnace.

If you click on the symbol the distribution of the oxides for the data set in question will be displayed in a diagram. The diagram shows you the graphic composition of the chemical glass analysis. It lists the quantity proportions in % by weight (Y) as a function of the oxide in question (X).

8.2 Wizard - data entry

To edit a glass (glass analysis), click on the wizard symbol () on the outside right of the corresponding line. The following describes the individual pages and the entry fields of the wizard for editing a glass:

8.2.1 Step 1: Description

Entry field	Description
Select data set	If you want to edit a particular glass, select the corresponding entry from the pulldown menu in the first line.
Designation	Allocate a name and brief description for the current data set. The designation will help you to find it faster in the general overview.
Date	This is where you can enter the date on which the glass was created.
Glass colour	In this field, you can enter the current glass colour for the glass.
Description	You can use this field to enter additional comments which are taken into account if you carry out a search.

8.2.2 Step 2/3: Chemical analysis

On these pages, you enter the oxide contents from your chemical glass analysis in percentages by weight. To make the display clearer, only the most important oxides are shown in Step 2. All the other oxides are then given on the next page.

8.2.3 Step 4: Desired Glass

At this point, you can define the current chemical analysis as the Nominal Glass. Basically, you can make any glass a Nominal Glass. If you create a new batch formula, you can calculate the charge and the properties on the basis of a previously defined Nominal Glasses. Nominal Glasses are glasses incorporating tolerances for the relevant oxide.

If you set the switch to YES, the glass analysis is taken over into the Nominal Glass database. If the current analysis has already been converted into a Nominal Glass, you can reverse this with the NO switch.

To start the calculation, click on the bottom right on the button *Calculate glass characteristics*. As soon as you have started the calculation, you will see a progress bar in the next window. Depending on the nature and scope of the analysis, the calculation may take a few seconds. The analysis covers the calculation of 230 different parameters (constants, temperatures, properties,...).

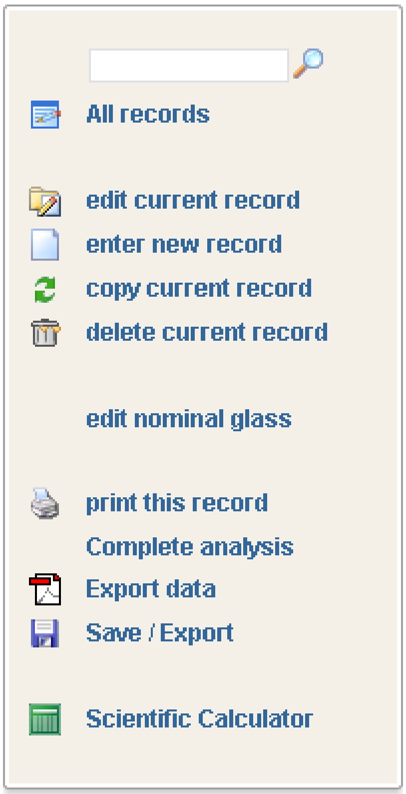
8.2.4 Step 5: Completion

As soon as the calculation is completed, you move to the final window, where you have various options for using the result. For this, click on one of the following entries with your mouse:

Display results of glass analysis in the overview	The wizard is closed and the program changes to the detailed view of the glass analysis.
Print current glass analysis	The wizard is opened and a new window is opened showing the print view of the current glass analysis.
Revise glass analysis (back to entry point 1)	By selecting this, you can go back to the first page of the wizard.

To start the selection, click on the button on the bottom right, *Execute selection*.

8.3 Detailed view



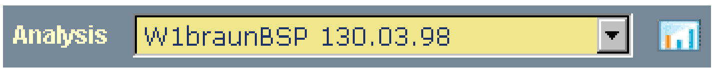
All records	Changes back to the General overview of the glass analyses.
Edit current record	Opens the wizard described in 8.2 for editing data.
Enter new record	Creates a new data set and opens the wizard for editing data.
Copy current record	Copies the current data set and adds the word "Copy" to the heading.
Delete current record	Deletes the current data set. If you have stated, in Setup, that every deletion must be confirmed, then you will be asked if you are sure that you want to continue; you should answer this with Yes (delete) or No (cancel).
Edit nominal glass	Converts the current glass to a Desired Glass. For more details, see Section 8.2.3.
Print this record	Opens a separate window and provides the glass analysis with the most important parameters for printing.
Complete analysis	The same function as print data set, but with all possible parameters.
Save/Export	Opens an export window in which you can define the export format and save the backup file.
Scientific calculator	Opens a separate window and provides you with a small pocket calculator with all the necessary functions.

Table 6 – Menu items: Glass analyses

8.3.1 Results window

You will find the results of the glass analysis on the right-hand side of the window. To retain a clear overview, all the calculated parameters are divided into groups. In the upper part, you will find basic values that you have entered in Step 1 of the wizard.

If you want to call up a particular glass that you have already prepared, select this from the yellow pulldown menu (selection).



If you click on the symbol  the distribution of the oxides for the data set in question will be displayed in a diagram. The diagram shows you the graphic composition of the chemical glass analysis. It lists the quantity proportions in % by weight (Y) as a function of the oxide in question (X).

8.4 Results of glass analysis

Every type of glass has the property necessary for its intended purpose, e.g. an optical glass has a particular refraction and an appliance glass has a particular chemical resistance. However, the properties of a glass, especially its viscosity, play a crucial part in production or moulding in particular. These properties are continuously monitored in every operation, and a large quantity of equipment is required for this.

The following explains in detail some of the parameters that have been calculated in the analysis:

8.4.1 Viscosity

Viscosity is the most important property, since it is of the greatest significance for the manufacturing and processing of glass.

Viscosity is a temperature-dependent parameter which is determined by the mobility of the structural particles of the substance in question. The forces to be overcome with this type of movement of particles are frictional forces. Viscosity is therefore also described as inner friction.

The movement of individual particles or components is made possible by the tearing apart of bonds. The energies necessary for this are applied in the melting process through thermal energies. If the temperature is increased all the time, the number of torn bonds increases and the viscosity is reduced. As the melt cools down, the bonds close again, which increases the viscosity.

The (dynamic) viscosity is designated using the symbol 'eta' and represents the force that is necessary to displace two parallel surfaces at a particular distance at a particular speed. If the viscosity is related to density, we talk about the kinematic viscosity.

However, it is essential for glass production and glass processing to have corresponding reference or fixed points for the entire temperature and viscosity range applied during glass manufacture. It is impossible to manage without these.

These defined fixed points are derived from particular stages in the glass production and are used primarily for determining the viscosity values of the glass that are most favourable for these production stages.

In addition, there are empirically determined key figures which are used in practice, since these affect the setting of the production machinery.

Since the viscosity of the glass changes by more than 13 decimal powers, the logarithm of the viscosity must be plotted as a function of the temperature.

If the viscosity curve runs steeply from 103 to 106 dPa s, the temperatures for the corresponding viscosities are relatively close to each other, i.e. the temperature range for processing the glass is short. Glass manufacturers refer to a glass of this type as being 'short', with the opposite type of glass being 'long'. The size of this temperature range is described as the length of the glass.

8.4.2 Fixed points for viscosity

Log η	Description
14.5	Lower cooling point/strain point. The temperature in question is also called the 15-hour relaxation temperature.
approx. 13-14.5	Transformation point Tg
13	Upper cooling point/annealing point
11.3	Dilatometric softening point/deformation point
approx. 8	Z_1 temperature
7.6	Littleton point, softening point
5	Flow point
4	Working point
4	Fixed point Eg (according to Dietzel and Brückner)

(eta in dPa s)

Glass melt ranges

Log η	Description
0 - 4	Melting
4 -10	Processing using various methods
11.3 - 14.5	Cooling, relaxing
14.5 -	Cooling down

Processing ranges

Log η	Description
1 - 3	Refining range
3 - 4	Killing
3 - 6	Manual processing range
3.2	Suction method
3.3	Drop method
4- 7.6	Processing range - pressing, blowing, drawing...
7.6 - 10	Still some processing using lamp
10 - 11	Transfer to cooling
13 - 14.5	Transformation range T_g

19 - 20	Glass roughly at room temperature: use

The details of viscosity were determined according to the following calculation models:

Log η		Description
1	Ledererova et al.	T for log(eta) = 2.0; 4.0; 7.65 and 13.1
2	Braginskii (Okhotin)	T=f(log(eta))
3	Braginskii	T for log(eta)= 3; 5; 7; 9; 11 and 13
4	Rodriguez Cuartas	T for log(eta)= 2; 3; 4; 7.6 and 13.0
5	Sasek et al.	T=f(log(eta))
6	Lakatos et al. - VFT	T=f(log(eta))
7	Herbert et al. - VFT	T=f(log(eta))
8	Lakatos et al.- Lead glass	T for log(eta)= 2.5; 4.5 and 13.0

Areas of validity

g: % by wt.; m: Mol.%; x: as desired or rest; -: no information

%	1	2 / 3	4	5	6	7	8
SiO2	x	x	62.7 - 72.8	x	x	53 - 56	52 - 62
B2O3	-	-	0 - 8.7	-	-	0 - 3	0 - 3
P2O5	-	-	-	-	-	-	-
Na2O	10.3 - 16.5	12 - 16	5.7 - 15.4	13 - 16	10 - 15	3 - 11	1 - 4
K2O	0 - 4.8	-	0 - 4.4	0.0 - 0.5	0 - 8	4 - 12	10 - 16
Li2O	-	-	-	-	-	-	0 - 1
Rb2O	-	-	-	-	-	-	-
TiO2	-	-	-	-	-	-	-
ZrO2	-	-	-	-	-	-	-
SnO2	-	-	-	-	-	-	-
CaO	4.5 - 11.4	5 - 12	4.8 - 12.2	7.0 - 8.5	9 - 13	-	0 - 8
MgO	0 - 4.7	0 - 5	0 - 5.0	2.5 - 4.5	0 - 4	-	0 - 3
BaO	0 - 4.5	-	0 - 2.8	-	-	-	0 - 5
PbO	-	-	-	-	-	26 - 30	23- 31
SrO	-	-	-	-	-	-	0 - 4
ZnO	-	-	-	-	-	-	0 - 5

CdO	-	-	-	-	-	-	-
BeO	-	-	-	-	-	-	-
FeO	-	-	-	-	-	-	-
MnO	-	-	-	-	-	-	-
CuO	-	-	-	-	-	-	-
CoO	-	-	-	-	-	-	-
NiO	-	-	-	-	-	-	-
Al2O3	0.2 - 6.1	0 - 5	0.1 - 5.5	0.5 - 3.0	0 - 7	0 - 3	-
Fe2O3	0.02 - 0.9	-	0 - 1.6	0.05 - 0.5	-	-	-
Cr2O3	-	-	-	-	-	-	-
As2O3	-	-	-	-	-	-	-
Sb2O3	-	-	-	-	-	-	-
Bi2O3	-	-	-	-	-	-	-
Ga2O3	-	-	-	-	-	-	-
As2O5	-	-	-	-	-	-	-
Sb2O5	-	-	-	-	-	-	-
Mn3O4	-	-	-	-	-	-	-
SO3	0 - 0.5	-	-	-	-	-	-
Cl	-	-	-	-	-	-	-
F	-	-	-	-	-	-	-

8.4.3 Glass formation

When the batch is heated, the batch components go through a series of interconnected individual processes which are both technical/physical and chemical in nature which affect glass formation. These reactions can be divided up as follows:

- Solid body reactions in the area of the grain contacts (silicate formation, CO2 development)
- Formation of carbonatic melts which encase the quartz grains
- Decomposition reactions which create bubbles (CO2...)
- Dissolution reactions of the carbonatic melts with quartz grains (formation of silicate melts)

The temperature rises constantly. Under the temperature conditions of the batch melting, these reactions take place more or less at the same time. The formation silicate melts is completed for Na2O-CaO-SiO2 glasses at approx. 1000°C, for PbO-SiO2 glasses at approx. 800°C and for Na2O-B2O3-SiO2 glasses at approx. 1100°C.

A further temperature increase in the melt is necessary, however, in order to achieve good homogenisation and refining of the glass in a reasonable time.

8.4.4 Relative Machine Speed RMS

$$RMS = \frac{S - 450}{(S - A) + 80}$$

S = Softening Point (log η = 7,65)

A = Annealing Point (log η = 13,0)

The value 1 or 100% occurs for a glass with the composition: 72.3% SiO2, 1.2% R2O3, 7.1% CaO, 1.9% MgO, 16.3% Na2O, 0.5% BaO and 0.7% B2O3.

The RMS is used in the production of certain container glasses and compares glasses with the above glass as regards their production behaviour.

8.4.5 Working Range Index WRI and Devitrification Index D

$$WRI = (S - A)$$

Working Range Index in °C

$$D = WRI - 160$$

Devitrification Index in °C

If the Working Range Index >160, this characterises a low devitrification index; if it is <160, devitrification is more probable. The Devitrification Index was introduced for this reason: If D is positive, devitrification is improbable, if D is negative, devitrification is more likely.

8.4.6 Gob Temperature G

$$G = 2{,}63(S - A) + S$$

Gob temperature in °C

The Gob Temperature is the temperature at which the glass has a viscosity of approx. 1000 dPa s. At this temperature, an optimum gob forms. Most machine operators prefer values <1200 °C.

8.4.7 Density

For the practical application of glass as a consumer object, the density is not particularly important. What is more interesting is the fact that the density is used as a calculation value for further properties and that density measurements can be used in practice to carry out, in a simple way, monitoring of the constancy of the glass composition.

$$\rho = \frac{m}{V}$$	The density rho is defined as mass per volume unit.

Glasses with a high density are generally glasses with a high lead oxide content, which particularly includes optical glasses.

Because the density depends on volume, there are differences as regards the heating history of glasses. A tensioned glass (mainly tensile stress in this case) undergoes an expansion which causes an increase in volume. The density of a tensioned glass is thus approx. 0.02 less than that of a destressed glass.

Considerable significance is assigned to density in combination with temperature, since it has a direct effect on glass flows in glass melting furnaces and furnaces.

The density decreases as the temperature rises, which is due to the fact that the cohesion of the individual components of the glasses is considerable reduced, so that thermal vibrations start which means that the volume expands.

8.4.8 Specific heat

Glass manufacture is a very heat-intensive process, which means that the thermal properties, especially specific heat, are very important.

$$c_p = \left(\frac{\Delta H}{\Delta T}\right)_p$$	The "true" specific heat at constant pressure is defined as a change in the enthalpy (heat retention) ΔH with the temperature ΔT

In practically all calculations, however, we are interested in what is called the "average" specific heat capacity tp_m (at constant pressure), which is determined between two temperatures T1 (mostly 0°C or 20°C) and T2:

$$\bar{c}_p = \frac{1}{T_2 - T_1}\int_{T_1}^{T_2} c_p dT$$	The "true" specific heat can also be determined from this equation

8.4.9 Optical properties

For optical glasses, certain key figures are important for evaluation of the individual glass types as regards their use in optical systems and in their calculation.

If a ray of light from air in which it has almost the maximum speed of c_0 hits a glass, it reduces its speed to c as a result of the interplay of the light with the ions making up the glass. If the light falls vertically, the course of the light does not change; but if it falls at an angle, a deflection occurs which is covered by the law of refraction; here, alpha or beta represents the angles of the ray of light in relation to the normal in air or in the glass and n is the refraction index of the glass.

$$n = \frac{c_0}{c} = \frac{\sin\alpha}{\sin\beta}$$

The main refraction index given is the refraction index ne, or sometimes the refraction index nd.

The refraction index depends on the wavelength of the light, the temperature and the pressure. It is therefore usual to give the value for n for 20°C and 1013.25 mbar. The wavelength for which a refraction index applies is attached as a letter index to the n. In technical optics, 13 refraction indices are applied for all sorts of different wavelengths of the spectrum.

Dispersion of light is closely associated with the light refraction. In the language of technical optics, dispersion is understood to mean the difference in the refraction indices of a medium for light of various wavelengths. The difference n_f-n_c is described as the average dispersion d.

$$\nu_d = \frac{n_D - 1}{n_F - n_C}$$

The relative dispersion is described by the ratio (n_f-n_c)/(n_d-1). The reciprocal relative density is described as the Abbe coefficient ny_d.

Apart from the major significance that light refraction and dispersion have for optical glasses, these properties are also interesting for the commercial glass industry, especially for lead glasses. High refraction values increase the shine of these glasses, which finally improves quality effectively.

For practical production, regular measurements of the refraction value can provide a relatively simple, sufficiently precise check on the consistency of the glass composition, since even minor deviations will lead to changes in the refractive value.

8.4.10 Surface tension

The surface tension of glass is important during the glass melt and in several stages of manufacture.

A particular within a body is attracted by all the neighbouring particles so that the resultant force is zero. If, on the other hand, a particle is on the surface, then there are no forces of attraction on one side and a force in the direction of the interior is created.

In order to take a particle from the inside to the surface, a certain degree of work is required. Bodies with a large surface therefore have more energy and are attempting to take on a state of less energy by reducing their surface area. Liquids therefore take on a spherical shape if possible, since the ratio of surface to volume is lowest in this form.

The enlargement of a surface assumes that particles will be transported from the inside to the surface, which requires an expenditure of energy. The energy that is required to form a new surface is described as specific free surface energy. Generally, the designation surface tension sigma is commoner.

8.4.11 Thermal expansion

The thermal expansion of glass is of major practical significance, especially as regards the lasting, break-proof melting of various glasses with each other and with other substances.

A precise knowledge of the progress of the thermal expansion of glasses is therefore an essential precondition for controlling some of the technological processes in glass production and processing.

The increase in volume of a body through thermal expansion happens on all sides. All isotropic bodies, including glass, expand at the same time in all directions to the same extent. This thermal expansion of the glass is caused by the fact that, as the temperature increases, the thermal energy present in the glass increases and, consequently, the particles begin to vibrate more. Atoms linked with each other by forces thus spread further apart, causing expansion.

$$\alpha = \frac{\Delta l}{\Delta T}$$

Thermal expansion is designated by the average longitudinal expansion coefficient (coefficient of linear expansion) alpha . It is the fraction of the length by which a bar of the material in question increases in length following a temperature increase of 1 degree:

For the commonest substances, within the temperature limits that are technically interesting, the α value does not change. This means that the change in length is proportion to the change in temperature. However, the change in length in the case of glass is not exactly proportional to temperature, and the coefficient of thermal expansion is therefore temperature-dependent. In practice, the average coefficient of volume expansion (cubic expansion coefficient) beta is now used. The following applies in general:

$$\beta \cong 3\alpha$$

8.4.12 Thermal conductivity

The thermal conductivity of glass is very low in comparison with other materials such as copper, aluminium and iron. It is therefore only important for particular areas of application.

Heat can be transported in glass through thermal conductivity and thermal radiation. At low temperatures the first process predominates, with the second occurring more at higher temperatures.

$$\frac{dQ}{dt} = -\lambda \cdot F \frac{dT}{dx}$$

According to the following definition equation, the thermal conductivity lambda is the quantity of heat dQ, which flows in the time dt vertically through the surface F at a temperature there of dT/dx.

In measurements, we generally obtain a total effective thermal conductivity which is made up of the figures for pure thermal conductivity and thermal radiation. Often, λ_{eff} is described as thermal conductivity for greater simplicity.

Because of the poor thermal conductivity of glass, certain products such as glass fibre matting, fibreglass and foam glass are used as insulation materials for all sorts of different applications. The thermal conductivity of foam glass is only approx. 1/20 of that of normal glass.

8.4.13 Elastic properties

A solid body suffers deformation as a result of a deforming force. If this deformation goes back completely after the force is removed, the body is described as being ideally elastic. Hooke's law states that the deformation D is proportional to the stress S applied.

The proportionality constant M occurring in this equation is generally described as a modulus. Depending on the nature of the deformation, there are various moduli. Their values depend on the composition; the moduli therefore represent material constants.

Tensile stress creates an expansion which is designated as the modulus of expansion (or the modulus of elasticity) E. A shearing stress causes shearing strain. The corresponding modulus G has a number of designations: the modulus of rigidity, shear modulus, twist modulus, torsion modulus. Finally, pressure on all sides causes compression, with the modulus of compression K.

$$\frac{\Delta d}{d} : \frac{\Delta l}{l} = \mu$$

With expansion, a transverse contraction occurs in the direction at right angles to this. If the relative expansion is dl/l and the relative transverse contraction is dd/d, then the ratio is described as the reciprocal of Poisson ratio

It can be deduced that the reciprocal of Poisson ratio my must lie between 0 and 0.5, A low reciprocal of Poisson ratio means that with a particular longitudinal expansion there is only a small transverse contraction.

8.4.14 Electrical properties

The use of glass in electrical engineering has increased considerably in recent years. Here, it is particularly the electrical properties at normal temperatures that are important, whilst for electrical glass melting the properties at higher temperatures are important.

Glass is amongst the poorer electrical conductors. Whilst, with good electrical conductors such as metals, the current is transported via free electrons, conduction is via ions in the case of glass.

The capacity of a substance to allow the transport of current by freely moving electrons or ions is described as its electrical conductivity. The electrical conductivity of a material is dependent on its specific electrical resistance rho.

$$\kappa = \frac{1}{\rho}\left[\frac{1}{\Omega cm}\right]$$

The specific electrical conductivity kappa (or sigma) of a material is designated as the reciprocal value of the specific electrical resistance.

As a consequence of its high rho value, glass is used as an electrical insulating material. As the temperature increases, the rho decreases, which is due to the fact that the conductive ions, especially the Na+ ions, become more mobile, thus improving conductivity.

Because kappa, due to the ion conductivity of glass, is also extremely temperature-dependent, every glass has very different values. At room temperature, a glass of this type, for example, has a kappa value of 10-13 to 10-14 Ohm-1 cm-1. In the melt temperature range, kappa increases to 0.1 to 0.3 Ohm-1 cm-1.

In practical use, the t_R8 value is often used for operating check measurements. This value is the temperature at which kappa=100 10-10 Ohm-1 cm-1.

This temperature varies, depending on glass composition, which means that if there is a change in the measured value, there are likely to be faults in the composition of the glass.

Both parameters, rho and kappa, are material constants which have characteristic values for glasses of different compositions.

8.4.15 Dielectric properties / permittivity

If a dielectric is placed between the plates of a capacitor, its capacity C increases compared to the capacity C_V measured in a vacuum to

$$C = \varepsilon \cdot C_V$$

In this equation, the proportionality factor epsilon is described as the permittivity coefficient epsilon_r or epsilon. The permittivity coefficient is better known as the dielectricity constant or figure.

The cause of this effect is that displacements of charges occur under the effect of an electric field. With an ion, the electron sheath can be deformed, or whole ions can be displaced in their location or can take up completely different positions. The first possibility is all the more likely, the greater the polarisability of the ion in question is. This means that there is a correlation with the refraction index for which a corresponding effect is decisive. For very high frequencies, the Maxwellian ratio applies with the refraction index n: $\varepsilon = n^2$ which is, however, not quite met for glass.

If a glass is inserted between the plates of a capacitor, not only is the capacity increased, but there is also a displacement of the phase angle between current and voltage. As the current passes through, the glass uses some electrical energy – the dielectrical losses. They become apparent in that the phase angle around the small angle theta becomes smaller than 90°. The quantitative dimension for this energy consumption is the tangent of this angle tan(theta), which is also described as the loss factor and which is equal to the proportion of effective power to idle power.

8.4.16 Strength

The tensile strength is one of the most important of the mechanical properties of glass. It has a major effect on the limit of usability of the glass as regards all sorts of mechanical stresses and also determines the temperature change resistance (TCR) to a large extent.

$$\sigma_z = \frac{F}{A}$$

The tensile strength is determined by the force F which tears a glass rod with the cross-section A.

In comparison to other materials such as steel or cast steel, glass has a low tensile strength.

The tensile strength of glass calculated theoretically from the bonding forces gives a value that is almost a hundred times the practical measurement results. This is due mainly to the structural micro-cracks and loose areas which also cover the glass surface as notch-shaped unevennesses.

The high risk of fracture of glass following blows and impacts is due to the insufficient tensile strength. If a glass surface is exposed to blows and impacts, it suffers indentations which lead to an enlargement and expansion of the surface, causing tensile stress. With most glasses, even light impacts are enough to exceed the elasticity limit, which leads to an immediate fracture.

$$\sigma_D = \frac{F}{A}$$

The compressive strength of glass is ten to fifteen times greater than its tensile strength. It is defined by the force F which must be applied to crush a glass plate with the bearing surface A.

As a result of the relatively good σ_D values, glass can be used as a building material in the form of glass bricks and similar.

Glass is relatively insensitive to compressive stress, and this property is used in practice by glass having high compressive stresses which considerably improves the tensile strength. These stresses are created by rapid cooling of the surfaces, especially of flat glasses, producing safety glass and prestressed glass products. With these special glass products, these technological treatments considerably increase impact resistance.

9 FURNACE

9.1 Overview

This module is used to manage all your melting furnaces. In addition, you also enter the settings here for all the *gases* used (incl. air analyses) and *oils*. These analyses are generally entered once and can be used again at many different points in the software.

In the area *Daily report*, you are provided with an overview of the furnace reports for the current furnace. A furnace report is the summary of all the relevant data and analyses (e.g. results of random samples) for a furnace.

The area *refractories* provides you with a database of the refractory material you have used. Here, you can assign several different parameters to every material.

The area *Design* provides you with a module with which you can carry out a heat permeability calculation on the basis of the refractory material you have used.

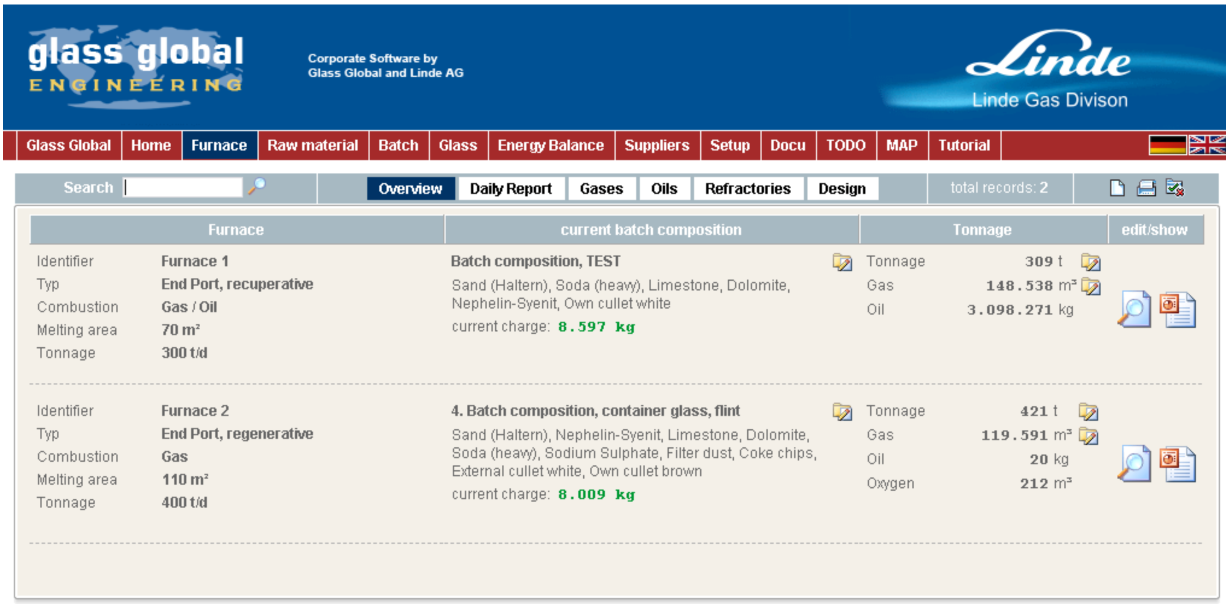


Figure 10 - Furnace data overview

The blue area underneath the main menu bar contains, on the left-hand side, a search box in which you can search in the current module. There are further sub-menu items in the middle of the blue bar, depending on module.

Daily report (recording of all the latest daily furnace and production data), gases (chemical analyses of the gases used), oils (chemical analyses of the oils used), refractories (management of refractory materials used) and Design (program for calculated the transport of heat in the furnace walls). "Overview" in the menu takes you back to the main overview of all melting furnace.

9.1.1 Functions of the overview page

You can access the furnace module by clicking on " Furnace " in the red menu bar. You will then be taken automatically to the overview of all furnaces available so far.

Column: Furnace	This column displays the most important parameters for the current furnace. These include furnace designation, furnace type, type of firing, melt surface and current tonnage.
Column: Current batch formula	This column shows the current batch formula which you are currently running at this furnace. Below this is the current charge in kg. The value comes from the batch formula calculation. If you click on the symbol, you will be taken straight to the wizard for editing the batch formulae.
Column: Tonnage	This displays the current tonnage and the consumed values of gas, oil, electricity (SEH) and oxygen (if available). If you click on the symbol next to the entry *Tonnage*, the wizard opens for editing the current data (furnace report).

9.2 Wizard - Data entry

To edit an existing furnace, click on the wizard symbol () on the outside right of the corresponding line. The following describes the individual pages and the entry fields of the wizard for editing furnace data:

9.2.1 Step 1: Description

Entry field	Description
Select data set	If you want to edit a particular data set, select the corresponding entry from the pulldown menu in the first line.
Designation	Allocate a name and brief description for the current data set. The designation will help you to find it faster in the general overview.
Furnace type	Select the furnace type (design) here. The selection list contains a number of predefined furnace types.
Commissioning	Enter the date when the furnace was first commissioned here.
Glass colour	Enter the glass colour which is currently produced with this furnace.
Glass type	Select the glass type here. The selection list contains a number of predefined glass types.
Description	You can use this field to enter additional comments which are taken into account if you carry out a search.

9.2.2 Step 2: Tonnage

Enter the melting capacity, nominal capacity and tonnage of your furnace here. This information is necessary for the calculation of batch formulae and raw material management. For example, the batch formula calculation is partly based on the settings for the melting capacity or the charge weight (min./max.).

9.2.3 Step 3: Charge weights

Enter the permitted charge weights here. This information is also necessary for calculating the batch formulae. In general, the weighed quantity in kg for a mixer fill is taken as the basis as the charge. However, you can define your own values too. Make sure, however, that the quantity ratios are right.

9.2.4 Step 4: Firing

This is where you define how and with what consumables your furnace is fired. Please enter all values (as far as you know them). If you click on the  symbol next to the entry *Standard Gas*, you will move straight to the wizard for editing the gas that is currently selected. You will find the same function next to the entry *Standard oil.*

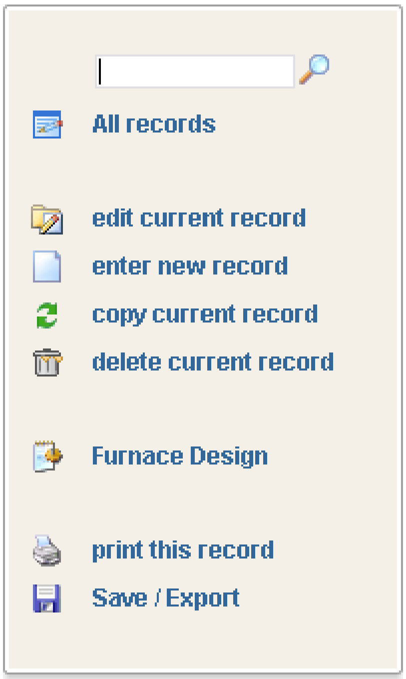
9.2.5 Step 5: Completion

As soon as you have completed the data entry, you move to the final window, where you have various options for using the result. For this, click on one of the following entries with your mouse:

Display summary of furnace data	The wizard is closed and the program changes to the detailed view of the furnace data.
Print current data set	The wizard is opened and a new window is opened showing the print view of the current furnace.
Revise furnace data (back to entry point 1)	By selecting this, you can go back to the first page of the wizard.

To start the selection, click on the button on the bottom right, *Execute selection*.

9.3 Detailed view



All records	Changes back to the general overview of the furnace data.
Edit current record	Opens the wizard for editing data.
Enter new record	Creates a new data set and opens the wizard for editing data.
Copy current record	Copies the current data set and adds the word "Copy" to the heading.
Delete current record	Deletes the current data set. If you have stated, in Setup, that every deletion must be confirmed, then you will be asked if you are sure that you want to continue; you should answer this with Yes (delete) or No (cancel).
Furnace design	Changes to the wizard for heat permeability calculation on the basis of the refractory material you have used.
Print this record	Opens a separate window and provides the furnace data with the most important parameters for printing.
Save/Export	Opens an export window in which you can define the export format and save the backup file.

Table 7 – Menu items: Furnace

10 APPENDIX

10.1 Molecular masses of elements and oxides

Element	Molecular mass	Oxide	Molecular mass
Si	28.0855	**SiO2**	60.0843
B	10.811	**B2O3**	69.6202
P	30.97376	**P2O5**	141.94452
Na	22.98977	**Na2O**	61.97894
K	39.0983	**K2O**	94.196
Li	6.941	**Li2O**	29.8814
Rb	85.4678	**Rb2O**	186.935
Ti	47.88	**TiO2**	79.8788
Zr	91.224	**ZrO2**	123.2228
Sn	118.710	**SnO2**	150.7088
Ca	40.078	**CaO**	56.0774
Mg	24.305	**MgO**	40.3044
Ba	137.33	**BaO**	153.3294
Pb	207.2	**PbO**	223.1994
Sr	87.62	**SrO**	103.6194
Zn	65.38	**ZnO**	81.3794
Cd	112.41	**CdO**	128.4094
Be	9.01218	**BeO**	25.01158
Fe	55.847	**FeO**	71.8464
Mn	54.9380	**MnO**	70.9374
Cu	63.546	**CuO**	79.5454
Co	58.9332	**CoO**	74.9326
Ni	58.69	**NiO**	74.6894
Al	26.98154	**Al2O3**	101.96128
Cr	51.9961	**Fe2O3**	159.6922
		Cr2O3	151.9904
As	74.9216	**As2O3**	197.8414

Sb	121.75	**Sb2O3**	291.4982
Bi	208.9804	**Bi2O3**	465.959
Ga	69.723	**Ga2O3**	187.4442
		As2O5	229.8402
		Sb2O5	323.497
		Mn3O4	228.8116
S	32.066	**SO3**	80.0642
H	1.00794	**H2O**	18.01528
O	15.9994	**CO2**	44.0098
Cl	35.453		
F	18.99840		

Table 8 – Molecular masses of elements and oxides

10.2 Vitrifiers/network formers

Formula	Designation	Raw material designation	Formula
SiO2	Silicon dioxide	Rock crystal	SiO2
		Vein quartz	SiO2
		Quartz sand	SiO2
B2O3	Bortrioxide	Borax (tinkal)	Na2B407*10 H2O
		Dehybor (dehydrated borax)	Na2B4O7
		Tincalconite	Na2B4O7*5 H2O
		Rasorite (kernite)	Na2B4O7*4 H2O
		Sassolite (boric acid)	H3BO3
		Colemanite	
P2O5	Phosphor pentoxide	Orthophosphoric acid	H3PO4
		Metaphosphoric acid	HPO3
		Dinatriumhydrogenphosphate	Na2HPO4
		Calcium phosphate (bone meal)	Ca3(PO4)2
		Aluminium orthophosphate	AlPO4
		Barium metaphosphate	Ba(PO3)2

Table 9 – Vitrifiers/network formers

10.3 Fluxing agents/network modifiers

Formula	Designation	Raw material designation	Formula
Na_2O	Sodium oxide	Soda	Na_2CO_3
K_2O	Potassium oxide	Potash	K_2CO_3
Li_2O	Lithium oxide	Eucryptite	$LiAl(SiO_4)$
		Spodumene	$LiAl(Si_2O_6)$
		Petalite	$Li(AlSi_4O_{10})$
CaO	Calcium oxide	Limestone/lime	$CaCO_3$
		Chalk	...
		Quick lime	CaO
		Dolomite	$CaCO_3*MgCO_3$
MgO	Magnesium oxide	Dolomite	...
		Magnesite	$MgCO_3$
		Calcined magnesia	MgO
BaO	Barium oxide	Witherite	$BaCO_3$
		Barite	$BaSO_4$
BeO	Beryllium oxide	Beryllium oxide (techn.)	BeO
		Beryllium carbonate	$BeCO_3$
SrO	Strontium oxide	Strontium oxide (techn.)	SrO

Table 10 – Fluxing agents/network modifiers

10.4 Intermediate oxides/amphoteric compounds

Formula	Designation	Raw material designation	Formula
Al_2O_3	Aluminium oxide	Alumina (calc.)	Al_2O_3
		Aluminium hydroxide	$Al(OH)_3$
		Potash feldspar (orthoclase)	$K_2O*Al_2O_3*6\ SiO_2$
		Natron feldspar (albite)	$Na_2O*Al_2O_3*6\ SiO_2$
		Leucite	$K_2O*Al_2O_3*4\ SiO_2$
		Nepheline	$Na_2O*Al_2O_3*2\ SiO_2$
		Lime feldspar (anorthite)	$CaO*Al_2O_3*2\ SiO_2$
		Kaolin(it)e	$Al_2O_3*2\ SiO_2*2\ H_2O$

		(Blast furnace) slag	
		Phonolite	
		Basalt	
		Nepheline Syenite	
PbO	Lead oxide	Bleiglätte (litharge)	PbO
		Red lead	Pb3O4
ZnO	Zinc oxide	Zinc white (techn.)	ZnO
TiO2	Titanium oxide	Titanium white (techn.)	TiO2
ZrO2	Zirconium oxide	Zircon	ZrO2
SnO2	Stannous oxide	...	SnO2

Table 11 – Intermediate oxides/amphoteric compounds

10.5 Refining agents

Formula	Raw material designation	Formula
Nitrates	Potassium nitrate	KNO3
	Salpeter/Natronsalpeter	NaNO3
	Ammonium salpeter	NH4NO3
Sulphides	Barium sulphide	BaS
	Zinc sulphide	ZnS
	(Blast furnace) slag	
"Oxides"	Arsenic/arsenic (III) oxide	As2O3
	Antimony oxide	Sb2O3
Sulphates	Sodium sulphate	Na2SO4
	Ammonium sulphate	NH4SO4
	Gypsum	CaSO4 (*2 H2O)
	Barite	BaSO4
Halogenides	Rock salt	NaCl
	Potassium chloride	KCl
	Ammonium chloride	NH4Cl
	Fluorspar	CaF2

Table 12 – Refining agents

10.6 Other raw materials

Designation	Raw material designation
Melt accelerators	Water, fluorides, boric acid, phosphates
Decolouring agents	Alkali and earth alkali nitrates, Co-, Ni- and Mn oxides, Se and -compounds
Colouring raw materials	Elements or compounds of Fe, Mn, Cu, Ni, Co, Cr, Se, S, Cd, Sb, Ce, Nd, U, Pt, Au, Ag...
Opacifiers	Fluorspar, Ca phosphates

Table 13 – Other raw materials

10.7 List of compound raw materials

The following is a list of a large proportion of the raw materials used in practice, show how they can be divided into oxides or compounds that cannot be further broken down. If, for example, the quantity of the component CaSO4 as a proportion of the raw material calcium sulphate is 99%, this means that the oxides CaO are present at 0.99*0.4119 and SO3 at 0.99*0.5881 parts.

Component	Oxide	Oxide	Oxide	Oxide	Oxide
Al(OH)3		0.6536 Al2O3		0.3464 H2O	
AlPO4	0.5820 P2O5	0.4180 Al2O3			
Al2O3*2 SiO2*2 H2O	0.4655 SiO2	0.3950 Al2O3		0.1395 H2O	
BaCO3		0.7770 BaO		0.2230 CO2	
Ba(OH)2		0.8949 BaO		0.1051 H2O	
Ba(PO3)2	0.4807 P2O5	0.5203 BaO			
BeCO3		0.3624 BeO		0.6376 CO2	
BaSO4		0.6570 BaO			0.3430 SO3
CaCO3		0.5603 CaO		0.4397 CO2	
CaCO3*MgCO3		0.3041 CaO 0.2186 MgO		0.4778 CO2	
CaO*Al2O3*2 SiO2	0.4319 SiO2	0.3665 Al2O3	0.2016 CaO		
Ca(OH)2		0.769 CaO		0.231 H2O	
Ca(OH)2*2 H2O		0.5092 CaO		0.4908 H2O	
Ca3(PO4)2	0.4576 P2O5	0.5424 CaO			

CaSO4		0.4119 CaO			0.5881 SO3
CaSO4*2 H2O		0.3257 CaO		0.2093 H2O	0.4650 SO3
FeCrO3		0.5124 Fe2O3 0.4876 Cr2O3			
H3BO3	0.5630 B2O3			0.4370 H2O	
HPO3	0.8874 P2O5			0.1126 H2O	
H3PO4	0.7242 P2O5			0.2758 H2O	
K2CO3			0.6816 K2O	0.3184 CO2	
K2O*Al2O3*4 H2O	0.5507 SiO2	0.2335 Al2O3	0.2158 K2O		
K2O*Al2O3*6 H2O	0.6476 SiO2	0.1832 Al2O3	0.1692 K2O		
KOH			0.8395 K2O	0.1605 H2O	
K2SO4			0.5405 K2O		0.4595 SO3
LiAl(SiO4)	0.4768 SiO2	0.4046 Al2O3	0.1186 Li2O		
LiAl(Si2O6)	0.6457 SiO2	0.2740 Al2O3	0.0803 Li2O		
LiAl(Si4O10)	0.7847 SiO2	0.1665 Al2O3	0.0488 Li2O		
MgCO3		0.4780 MgO		0.5220 CO2	
Mg(OH)2		0.6911 MgO		0.3089 H2O	
MgSO4		0.3348 MgO			0.6652 SO3
Na2B4O7	0.6920 B2O3		0.3080 Na2O		
Na2B4O7*4 H2O	0.5095 B2O3		0.2268 Na2O	0.2637 H2O	
Na2B4O7*5 H2O	0.4780 B2O3		0.2128 Na2O	0.3092 H2O	
Na2HPO4	0.4998 P2O5		0.4366 Na2O	0.0636 H2O	
Na2O*Al2O3*6 SiO2	0.6874 SiO2	0.1944 Al2O3	0.1182 Na2O		
NaOH			0.7748 Na2O	0.2252 H2O	
Na2SO4			0.4363 Na2O		0.5637 SO3

Table 14 – Compound raw materials

11 System Requirements

11.1 Internet connection

Making a connection online can take a varying amount of time. This may also be due to the technical capabilities of your hardware and software. To ensure fast page display and smooth data transmission online, please note the minimum configuration that we recommend.

Computer capacity	Pentium2 with 600 MHz and 256 MB free memory
Operating system	At least Windows98 or higher
Screen resolution	The best screen resolution for our web pages is 1024x768 pixel. Your screen resolution should not go below the minimum of 800x600 pixel if possible.
Browser	The layout of the web pages is designed for Microsoft© Internet Explorer 5.5™ or higher. Netscape browsers from 7.1 do not support all layouts.
JavaScript	If Java is not installed on your computer, you can download it free of charge from the internet, at http://www.java.com. Depending on your operating system, the program file is between 8 and 20 MB. JavaScript must be released in your navigation program. This is generally set this way. If not, please follow these instructions: **Netscape** In the menu "Edit - Settings - Advanced", set the setting for Java ("Activate Java") and JavaScript ("Scripts & Plugins - Activate JavaScript for Navigator"). **Internet Explorer** Select the menu "Tools - Internet Options". A dialogue will appear with a series of tabs. Select "Security" and click on "Adjust Step". A list of security settings will appear, in which you should set the option "Microsoft VM-Java Settings" to "High security". Then you should select Activate at "Scripting-Active Scripting" and activate "Scripting of Java-Applets".
Download	Download information is generally available in pdf format and can be viewed with Acrobat Reader. If you have not yet installed Acrobat Reader, you can download it free of charge from the following address http://www.adobe.com/products/acrobat/readstep2.html
Flash animations	"Flash" is a format for animations on internet pages. To display bar charts (e.g. energy balance, glass oxides,...), you will need a special Plugin (a small additional program for your navigation program), which you can download free of charge from www.macromedia.com.

12 GUARANTEE

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13 List of illustrations and tables

13.1 List of illustrations

13.2 List of tables