TriBatch™ User's Guide
Version 1.1.0

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Table of Contents

Revision History

Version 1.1.0 (1-Apr-2009)

- Additional Features:
  - Added TriBatch Lite license.
  - Added Excel 2007 compatibility.
  - Completed missing sections in the manual.
- Bug fixes:
  - Various minor bugs fixed.

Version 1.0.1 (21-May-2007)

- Additional Features:
  - Added **Default Options** command in the **Settings** menu to enable saving and restoring all of the default settings.
- Bug fixes:
  - Fixed TriBatch problems that occurred when running with Windows Regional Options different from standard "English (United States)" standards and formats.
  - Removed **Full Screen** option from **Excel View Setting** because it reverts to the standard Excel menu bar.
  - Fixed a bug that affected moving oxides when calculated Min/Max values were displayed.
  - Updated Batch Sheet Layout dialog to reflect actual row and column titles.

Version 1.00 (01-Apr-2007)

- Initial release.

Version 0.83 – Beta (01-Jan-2006)

- Beta release of the program for user testing.

Version 0.81 – Alpha (20-May-2004)

- Initial Alpha release of the program for user testing.

License and Registration

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Registering TriBatch

An unregistered copy of TriBatch can only be used in Demo mode. The only limitation imposed by the demo mode is that the target composition is limited to one of four demo target compositions.

In order to register your copy of TriBatch, and obtain registration code from Trimill, you must purchase a **TriBatch Lite** license or a **TriBatch Pro** license.

TriBatch License Cost

The licenses and registration codes can be obtained from Trimill for the following prices:

Pro license

- 1st license: CAD 1,900.00;
- 2nd - 5th license: CAD 1,400.00 for each additional license;
- 6th - 10th license: CAD 900.00 for each additional license;
- 11th license and higher: CAD 600.00 for each additional license.

Lite license with limited functionality (no glass cost optimization and no Min/Max analysis):

- CAD 290.00 for each license.

TriBatch Support and Upgrades Policies

Pro license

- One year of free email support;
- Free service and minor version upgrades (for example from version 1.1.0 to 1.2.1 or 1.2.0);
- Half price major version upgrades (for example from version 1.1.0 to 2.0.0).

Lite license

- Three months of free email support;
- Free service and minor version upgrades (for example from version 1.1.0 to 1.2.1 or 1.2.0);
- Half price major version upgrades (for example from version 1.1.0 to 2.0.0);
- Discount equivalent to the full cost of Lite license for upgrade to Pro license.

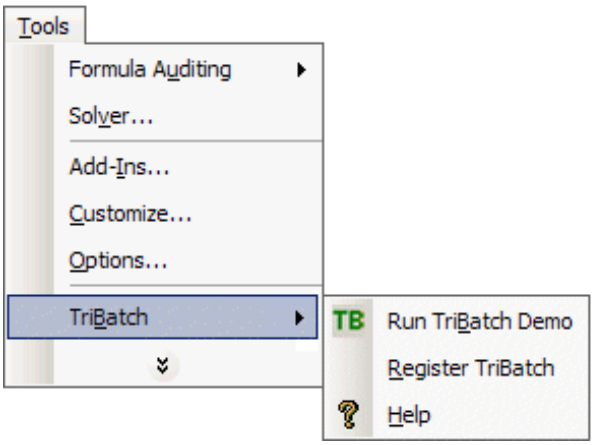
Obtaining a Request Code

Each license carries a registration code that is uniquely tied to a single computer. In order to obtain the registration code, you must supply the Request Code for that is unique to your computer to Trimill.

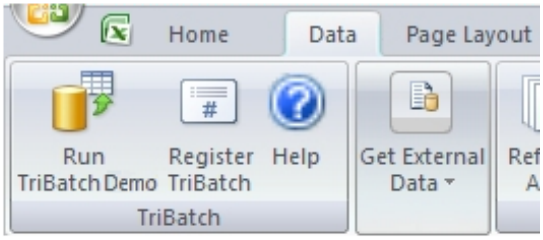
To obtain the Request Code, select **Register TriBatch** (or **Upgrade TriBatch** if you already have a TriBatch Lite license) on Excel's **Tools** menu. In Excel 2007 click on **Register TriBatch** or **Upgrade TriBatch** in the TriBatch group on the left side of the **Data** tab.

Next, click on the **Enter Registration Code** button in the **Register TriBatch** dialog. This will display the **Enter Registration Code** window which will display the **Request Code for This Computer**.

Excel 2003



Excel 2007



Registering Over the Internet

We offer online registration on our homepage. We use PayPal service for credit card orders. All orders that are less than USD 200 must be processed this way.
http://www.trimill.com/TriBatch/Register.htm

Registering Through Email or Mail (CAD 300 or more)

Only for orders of CAD 200 or more you can copy/paste the **Order Form** and email it to info@trimill.com. We accept the following types of payment:

- *Personal check or cashier's check,*
- *International money order;*
- *Cash by registered mail, at your own risk!*
- *Purchase Orders accepted from recognized businesses and institutions (Net 30).*

The payment should be mailed to:

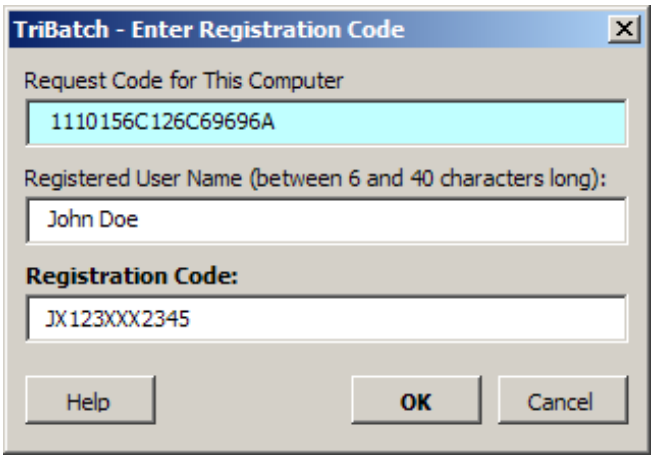
Trimill Industrial Systems
530 West 19th Street
North Vancouver, BC
CANADA V7M 1X9

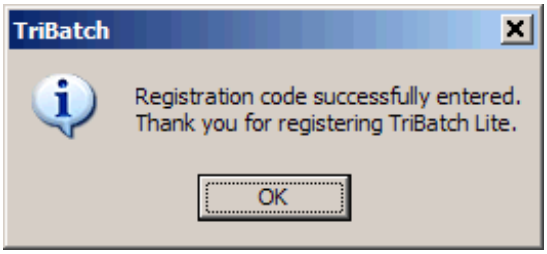
Entering Registration Code

As a licensed user you will receive your registration code from Trimill. You will also receive a receipt for your records, indicating that the program is properly registered. For multi-user and/or networked versions, a hard copy of the site license certificate can be requested for your records.

Click on the [**Enter Registration Code**] button in the TriBatch start-up window (shown when you click on **Register TriBatch** on Excel's **Tools** menu). In Excel 2007 click on **Register TriBatch** or **Upgrade TriBatch** in the TriBatch group on the left side of the **Data** tab.

You will be prompted to enter your **Registered User Name** and the corresponding **Registration Code**. Once entered, your User Name will be displayed in the splash screen every time you start TriBatch and in the About TriBatch dialog (click **About TriBatch** on the TriBatch **Help**).





TriBatch Order Form

Please fill out and send this order form together with your payment to:

info@trimill.com

Trimill Industrial Systems
530 West 19th Street
North Vancouver, BC
CANADA V7M 1X9

TriBatch Pro License(s)

( ) 1st license CAD 1,900.00

\+ Additional licenses to the same name:

Additional license 2-5, ____ x CAD 1,400.00 = _____

Additional license 6-10, ____ x CAD 900.00 = _____

Additional license 11 +, ____ x CAD 600.00 = _____

TriBatch Lite License(s)

( ) Number of licenses ____ x CAD 290.00 = _____

Total CAD _____

Registered User Name (your name **OR** company name - please check off):

( ) Name _____

( ) Company _____

Address _____

City _____

Province/Country _____

Zip/Postal code _____

Phone/FAX _____ / _____

E-mail address _____

Payment:

( )Check ( )Money Order ( )Cash ( )Purchase Order #: _____

Installing and Uninstalling TriBatch

Installing TriBatch

To install **TriBatch** on your computer, please follow the procedure outlined below:

- Download TriBatch setup file **TriBatch_xxxxxx_Setup.exe** to any folder on your computer.
  Note that **xxxxxx** in the file name indicates the version number, for example **TriBatch_010100_Setup.exe** specifies version 1.1.0 (01.01.00).
- Close all running programs. In particular, be sure to close Excel.
- Run the TriBatch Setup program (double-click on **TriBatch_xxxxxx_Setup.exe** in the Windows explorer or run it through the Windows **Start** | **Run...** dialog), and follow the prompts.
- The Setup program will install TriBatch add-in files, the support files and optional online help and example files in a folder that you specify.
- After the Setup program has successfully completed the installation, you can start Excel. TriBatch add-in will be **installed** and **loaded** in all supported versions of Excel that are installed on your computer.

System Requirements

- Operating system: **Windows** 98, ME, 2000, XP or Vista.
- Installed Microsoft® **Excel** version 2000, 2002 (XP), 2003, or 2007.
  Note that Excel 97 and earlier versions are not supported.
- Installed **Solver** add-in that comes with Excel.

Important Note Regarding Solver

*There is a known problem with Solver add-in in **Excel 2000 SP3** (service pack 3). which causes Solver to crash when called from another program. If you have this version of Excel installed on your computer (you can check this by clicking **About Microsoft Excel** on the Excel's **Help** menu), then you must manually replace the installed **Solver.xla** file with the one that was supplied on the original Microsoft Office 2000 installation CDs.*

*For your convenience the TriBatch installation includes a copy of the original **Solver.xla** for the **English version** of **Excel 2000**. However, we cannot guarantee that this version will work with international versions of Excel.*

The Solver.xla used by Excel 2000 is usually located in:
C:\Program Files\Microsoft Office\Office\Library\Solver

The Solver.xla supplied with TriBatch usually located in:
C:\Program Files\Trimill\TriBatch

Important Note Regarding Windows Vista

For compatibility reasons, TriBatch online help file was created using Windows Help (WinHlp32.exe).

Windows Help is a Help program that has been included with Microsoft Windows versions starting with the Microsoft Windows 3.1 operating system. However, starting with the release of Windows Vista, the Windows Help program is not included as a feature of Windows.

In order to display TriBatch on-line help in Windows Vista and Windows Server 2008 you must download and install WinHlp32.exe for Windows Vista or Windows Server 2008. See Microsoft Knowledge Base Article #917607.

Permanently Uninstalling TriBatch

To uninstall TriBatch and permanently remove from your computer, please follow the procedure outlined below.

Step 1

- Unload TriBatch using Excel's add-in manager. This is not a necessary step, but it is highly recommended in order to avoid a **File not found** error message next time you start Excel.
- Close Excel if it is running.

Step 2

Option a)

- Click the Windows **Start** button, point to **Settings**, and then click **Control Panel**.
- Double-click the **Add/Remove Programs** icon.
- Click **Trimill TriBatch** on the **Install/Uninstall** tab, and then click **Add/Remove**.
- Confirm that you wish to uninstall TriBatch and all of its components by clicking on the [Yes] button.

Option b)

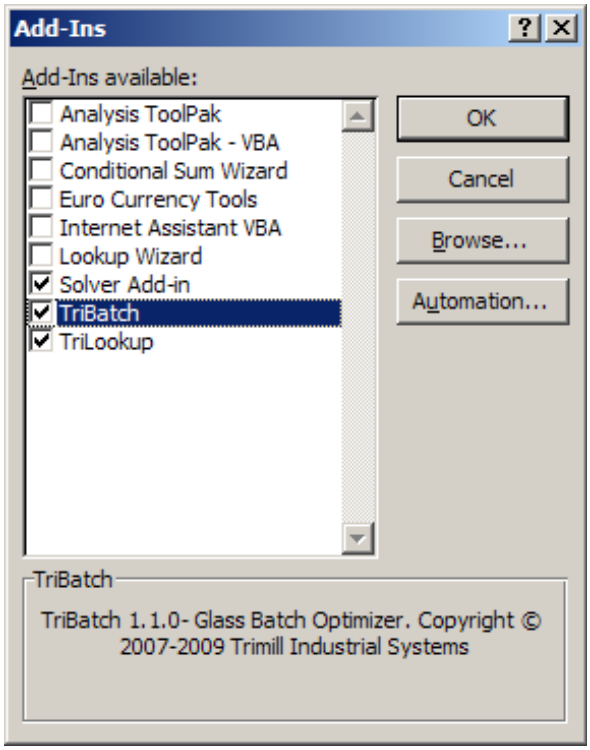
- Click the Windows **Start** button, point to **Programs** | **TriBatch**, and click on **Uninstall TriBatch**.
- Confirm that you wish to uninstall TriBatch and all of its components by clicking on the [Yes] button.

Loading TriBatch Using Excel's Add-in Manager

If you have previously unloaded TriBatch but haven't uninstalled it from your computer, you can load it again using Excel's add-in manager.

To load TriBatch, please follow the procedure outlined below:

- On the **Tools** menu, click **Add-Ins** (in Excel 2007 click on the **Office Button** , **Excel Options** (bottom right), Add-Ins, select **Manage: Excel Add-ins** and click **Go...**).
- In the **Add-Ins available** box, select the check box next to **TriBatch** and then click the [OK] button.



Unloading TriBatch Using Excel's Add-in Manager

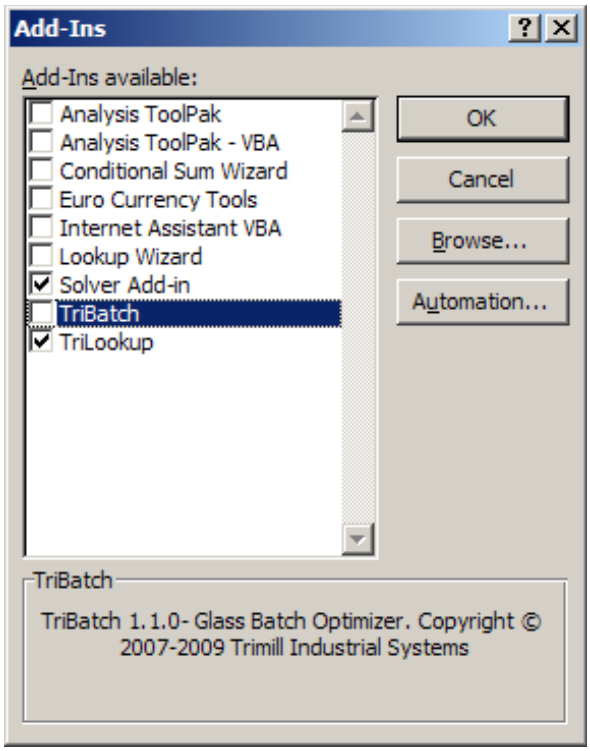
If you are not using the TriBatch add-in often, you can unload it to conserve memory and reduce the time it takes to start Excel. Unloading TriBatch removes its custom functions from Excel, but the TriBatch add-in program remains installed on your computer so you can easily load it again.

You should also unload TriBatch before permanently uninstalling it.

Note: When you unload the TriBatch add-in from Microsoft Excel, it is not removed from your computer system.

To unload TriBatch, please follow the procedure outlined below:

- On the **Tools** menu, click **Add-Ins** (in Excel 2007 click on the **Office Button** , **Excel Options** (bottom right), Add-Ins, select **Manage: Excel Add-ins** and click **Go...**).
- In the **Add-Ins available** box, clear the check box next to **TriBatch** and then click the [OK] button.


Add-Ins
Add-Ins available:
Analysis ToolPak
Analysis ToolPak - VBA
Conditional Sum Wizard
Euro Currency Tools
Internet Assistant VBA
Lookup Wizard
Solver Add-in
TriBatch
TriLookup
OK
Cancel
Browse...
Automation...
TriBatch
TriBatch 1.1.0- Glass Batch Optimizer. Copyright © 2007-2009 Trimill Industrial Systems

Using TriBatch

For latest news, see http://www.trimill.com/TriBatch/TriBatch.htm

Introduction to TriBatch

TriBatch is advanced batch calculator and batch optimizer software for glass industry. It is capable of basic batch calculation, as well as:

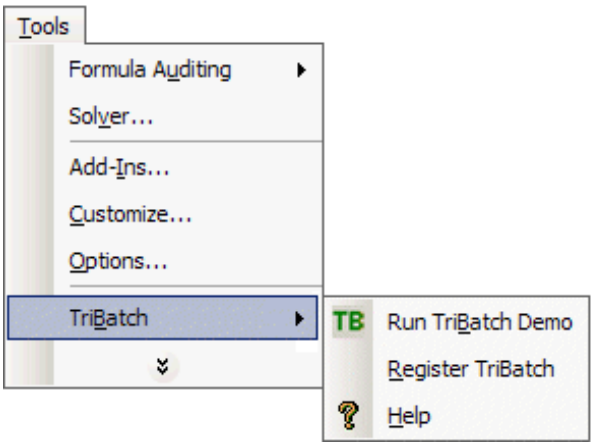
- Batch optimization for closest-to-target glass composition;
- Batch optimization for minimum glass cost with constraints;
- Assigning tolerances to target oxide percentages in glass;
- Using oxide composition error weighing coefficients for optimization;
- Grouping oxides;
- Assigning oxide saturation limits in glass;
- Specifying raw material quantities as percentage of other raw materials or total batch weight (used for minor ingredients;
- Specifying raw material carryover losses;
- Using raw material composition tolerances.

TriBatch is an add-in for Microsoft® Excel versions 2000, 2002, 2003 and 2007.

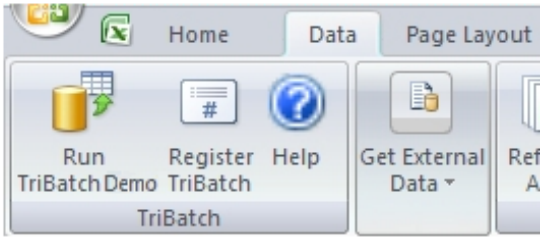
Starting TriBatch

After installing (and registering) TriBatch, you can start it by selecting **Run TriBatch** (Demo, Lite or Pro) from Excel's **Tools** menu. In Excel 2007 click on **Run TriBatch** in the TriBatch group on the left side of the **Data** tab.

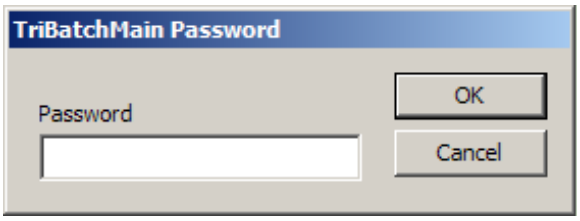
Excel 2003



Excel 2007

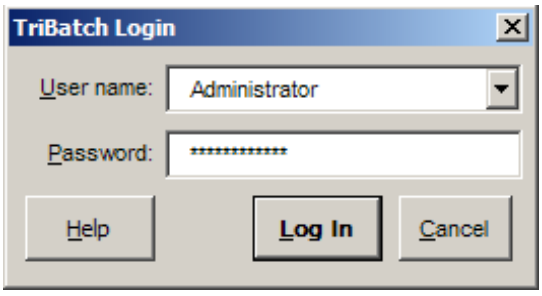


Note: Before starting, TriBatch will display a **TriBatchMain Password** (see below) dialog. To continue, click on the **Cancel** button, without entering a password. This is required because TriBatch code is password protected.



If you haven't created additional users using the Users dialog, located in **Users Names and Passwords…** in the Settings menu, then TriBatch will automatically initialize, create an empty batch sheet with a default number of raw materials and oxides and load the default raw material database.

If additional users have been created, then you will first have to log in by selecting a **User name** and password (if any) and clicking on the **Log In** button.



Demo Mode

An unregistered copy of TriBatch can be only used in Demo mode. The only limitation imposed by the demo mode is that the target composition is limited to one of four demo target compositions, as follows:

Demo Composition #1

SiO2	Al2O3	Na2O	K2O	CaO	MgO	Fe2O3	B2O3	SO3
60	2	18	2	8	4	0	6	Free

Demo Composition #2

SiO2	Al2O3	Na2O	K2O	CaO	MgO	Fe2O3	B2O3	SO3
60	2	18	2	12		Free	6	Free

Demo Composition #3

Ox01	Ox02	Ox03	Ox04	Ox05	Ox06
68.5	2.5	6.5	2.2	15.8	4

Demo Composition #4

Ox01	Ox02	Ox03	Ox04	Ox05	Ox06	Ox07	Ox08	Ox09	Ox10
6	12	26	4	3	2	3	4	5	22

Ox11	Ox12	Ox13	Ox14	Ox15	Ox16	Ox17	Ox18	Ox19	Ox20
3	1	2	3	1	1	0.3	0.2	1	0.5

TriBatch Lite

If you have purchased a TriBatch Lite license, the following TriBatch features will not work unless the target composition matches one of four demo target compositions:

- Min/Max Analysis
- Solve for Minimum Glass Cost (see **Calculate Menu**)
- Export Batch Sheet to a Workbook (see **File Menu**).

In order to enable the above features, you must purchase a TriBatch Pro license.

TriBatch Pro

If you have purchased a TriBatch Pro license, all TriBatch features will work regardless of the target composition. The extra features compared to the TriBatch Lite license are:

- Min/Max Analysis
- Solve for Minimum Glass Cost (see **Calculate Menu**)
- Export Batch Sheet to a Workbook (see **File Menu**).

TriBatch Online Help and Examples

TriBatch add-in package includes the following online help and examples:

- Online help file.
- Sample batch sheets that demonstrate different capabilities of the TriBatch program.

The online help can be accessed from **TriBatch** by clicking **TriBatch Help** on the **Help** menu. See section **Important Note Regarding Windows Vista** on page 9 for details on how to display TriBatch online help in Windows Vista.

The sample batch sheets can be accessed by clicking **Open Example Batch Sheet** on the **File** menu and then selecting one of the example files.

Batch Sheet

Below is an example of a TriBatch batch sheet with all of the rows and columns shown:

Batch and Glass Properties Cells

1	Batch Sheet Name	TriBatch Demo Example 6	
2	Comment 1	Demo glass #2 (CAO & MGO grouped together) soved for min. glass cost, maximum 0.3% of SO3 in glass, mixed cullet at 20% of total batch	
3	Comment 2	No targets (free) for Fe2O3 and SO3, Explicit Max/Min target composition tolerances for all oxides, Min/max analysis, All Rows & columns shown	
4	Batch Sheet Status	Solved for Minimum Glass Cost *Not Saved*	
5	Batch Weight	200.00	kg
6	Glass Weight	161.34	kg
7	Loss of Ignition	19.33	%
8	Batch Cost	59.46	$/Ton
9	Glass Cost	73.71	$/Ton
10	Standard Error	0.431	%

Raw Material Properties Columns

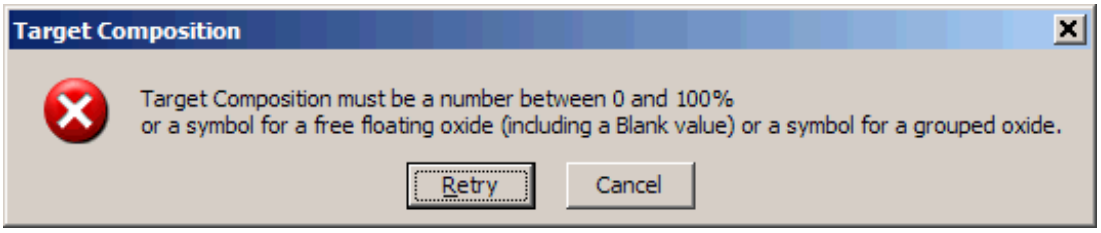
11	12	13	14	15	16	17	18												22			23	24
							19	20	21	% Ox in RM, Max +/- Deviation													
No	Raw Materials	Batch kg	Price $/Ton	Carryover Loss %	Weighing Err. ± kg	Ox. Tol. Coeff.	Fixed as... Q'ty	Unit	% of...	1 SiO2	2 Al2O3	3 K2O	4 Na2O	5 CaO	6 MgO	7 Fe2O3	8 B2O3	9 SO3				LOI %	Ox Yield kg
1	Silica Sand 1	72.30	13.00	0.10	1.000					98.00	0.34					0.10						1.56	71.11
2	Soda Ash	33.22	130.00	2.00	0.500								57.90					2.20				40.93	19.23
3	Nepheline Syenite (amber	5.00	64.20	0.20	0.500					54.00	21.50	8.20	6.80	4.00		0.40						5.10	4.74
4	Borax	19.13	250.00	23.00	0.500								21.70			0.00	48.80	0.50				29.23	10.42
5	Dolomite	27.08	26.70	0.10	0.500					1.00	0.40			31.10	20.10	0.40						47.00	14.34
6	Potash (Hydrated)	3.26	125.00	0.50	0.500							57.00										43.00	1.85
7	Cullet - Mixed	40.00	10.00	0.10	2.000	1.0	20.0	% of	TOTAL BATCH	61.00	4.10	1.41	14.64	9.98	2.09	0.21	5.63	0.30		0.78	39.65
										1.00	0.25	0.11	0.38	0.70	0.30	0.10	0.58	0.00			
										-1.00	-0.25	-0.11	-0.38	-0.70	-0.30	-0.10	-0.58						
	TOTAL BATCH	200.00																					

Glass Composition Rows

25	Oxides:	SiO2	Al2O3	K2O	Na2O	CaO	MgO	Fe2O3	B2O3	SO3
26	Target Composition (Total = 100.00%)	60.00	2.00	2.00	18.00	12.00	~	Free	6.00	Free
27	Max (+) Deviation % (Default = +2.5% of Target)	1.00	0.10	0.25	0.50	0.30	0.20	0.35	0.25	
	Max (-) Deviation % (Default = -2.5% of Target)	-1.00	-0.10	-0.25	-0.50	-0.30	-0.20	0.00	-0.15	
28	Error Weigh. Coef. [0..10]									
29	Oxide Evaporation %									
30	Oxide Saturation %									0.30
31	Calc. Composition (Total = 100.00%)	60.82	1.90	1.75	17.50	11.70	~	0.18	5.85	0.30
32	Max Composition %	61.58	2.07	2.00	17.98	12.16	"	0.21	6.18	0.30
	Min Composition %	60.06	1.73	1.51	17.03	11.26	"	0.15	5.52	0.30
33	Deviation (%)	0.82	-0.10	-0.25	-0.50	-0.30	~	-	-0.15	-
34	Max (+) Deviation %	1.58	0.07	0.00	-0.02	0.16	"	-	0.18	-
	Max (-) Deviation %	0.06	-0.27	-0.49	-0.97	-0.74	"	-	-0.48	-
35	Ox Group Breakdown (%)					7.81	3.89			
36	Max Composition %					8.19	3.97			
	Min Composition %					7.50	3.77			

Types of cells

- The cells with a **grey background** are row or column titles and cannot be modified by the user.
- The cells with a **white background** contain user entered data and can be freely edited by the user.
  Note that there are certain restrictions placed on the values that can be entered into some of the data cells. For example, if you enter a negative value in the **Target Composition** row, you will get the following warning:



- The cells with a **light blue background** show the results of batch sheet calculation and cannot be modified by the user.

Content of Batch Sheet Cells, Rows and Columns

Batch and Glass Properties Cells

1	Batch Sheet Name	TriBatch Demo Example 6	
2	Comment 1	Demo glass #2 (CAO & MGO grouped togethe	
3	Comment 2	No targets (free) for Fe2O3 and SO3, Explicit	
4	Batch Sheet Status	Solved for Minimum Glass Cost *Not Saved*	
5	Batch Weight	200.00	kg
6	Glass Weight	161.34	kg
7	Loss of Ignition	19.33	%
8	Batch Cost	59.46	$/Ton
9	Glass Cost	73.71	$/Ton
10	Standard Error	0.431	%

1. **Batch Sheet Name**

   Batch Sheet file name. To change the file name use **Save as** on the **File** menu, or rename the file before opening it.

2. **Comment 1**

   First line of comments. You can type any kind of text here and it will be saved with the batch sheet.

3. **Comment 2**

   Second line of comments.

4. **Batch Sheet Status**

   Shows if the batch sheet has been calculated, solved or saved.

5. **Batch Weight**

   Calculated total batch weight - the sum of all raw material weights.

6. **Glass Weight**

   Calculated glass weight for the given batch - the sum of all oxide yield weights.

7. **Loss of Ignition (%)**

   Calculated loss of ignition for the whole batch (in %).

8. **Batch Cost**

   Calculated batch cost per unit weight, based on raw material prices and their weights in the batch.

9. **Glass Cost**

   Calculated glass cost per unit weight based on raw material prices, their weights in the batch and their individual losses of ignition.

10. Standard Error (%)

Weighted standard error of the calculated glass composition, compared to the target glass composition.

Raw Material Properties Columns

11	12	13	14	15	16	17	18			22						23	24
							19	20	21	% Ox in RM, Max +/- Deviation							
		Batch	Price	Cargover	Weighing	Ox. Tol.	Fixed as...			1	2	3	4	5	6	LOI	Ox Yield
No	Raw Materials	kg	$/Ton	Loss %	Err. ± kg	Coeff.	Q'ty	Unit	% of...	SiO2	Al2O3	K2O	Na2O	CaO	MgO	%	kg
1	Silica Sand 1	72.30	13.00	0.10	1.000					98.00	0.34					1.56	71.11
2	Soda Ash	33.22	130.00	2.00	0.500								57.90			40.93	19.23
3	Nepheline Syenite	5.00	64.20	0.20	0.500					54.00	21.50	8.20	6.80	4.00		5.10	4.74
4	Borax	19.13	250.00	23.00	0.500								21.70			29.23	10.42
5	Dolomite	27.08	26.70	0.10	0.500					1.00	0.40			31.10	20.10	47.00	14.34
6	Potash (Hydrated)	3.26	125.00	0.50	0.500							57.00				43.00	1.85
7	Cullet - Mixed	40.00	10.00	0.10	2.000	1.0	20.0	% of	TOTAL BATCH	61.00 1.00 -1.00	4.10 0.25 -0.25	1.41 0.11 -0.11	14.64 0.38 -0.38	9.98 0.70 -0.70	2.09 0.30 -0.30	0.78	39.65
	TOTAL BATCH	200.00															

11. No

Raw material number (maximum is 25).

12. Raw Materials

Specify raw material names in this column.

13. Batch

Calculated batch weight for each raw material. This column includes TOTAL BATCH at the bottom, which is the calculated total batch weight (sum of all raw material weights).

14. Price

Specify prices for each raw material in this column. Blank value = 0.

15. Carryover Loss %

Specify carryover losses in % for each raw material in this column. Blank value = 0.

Carryover loss means that a percentage of the raw material is lost before it is melted. It is usually picked up by the flue gas and taken out through the stack. Therefore, the loss of ignition for that raw material will increase, as well as the overall loss of ignition.

If the loss of an oxide occurs after melting due to evaporation, then specify it in the **Oxide Evaporation %** row.

16. Weighing Err.

In this column specify maximum weighing errors when adding each raw material to the batch. Blank value = ±0. Used in the Min/Max Analysis.

17. Ox. Tol. Coeff.

Specify the oxide tolerance multiplier for the raw material's maximum and minimum deviations from nominal composition. These values are used in the Min/Max Analysis

[0..10]." Blank value = 0, in which case only the nominal raw material composition is used.

18. Fixed as...

Specify whether the batch weight of each raw material is fixed in any way.

19. Fixed as... **Q'ty**

If the raw material is fixed as a percentage of another raw material or TOTAL BATCH, then specify that percentage in this column. If the raw material has a given batch weight, then specify that weigh. Leave blank if the raw material is not fixed.

20. Fixed as... **Unit**

This column shows one of the following:

- Weigh unit if the raw material batch weigh is given;
- % if the raw material weight is fixed as a percentage of another raw material or TOTAL BATCH;
- Blank if the raw material is not fixed.

21. Fixed as... **% of...**

If the raw material weight is fixed as a percentage of another raw material or TOTAL BATCH, then specify what it is fixed in relation to in this column. Leave blank if the raw material has a given batch weigh or if it is not fixed.

The easiest way to do this is to pick the name of the raw material from the list after clicking on the down arrow nest to the cell.

22. Oxides (Raw Materials Composition Table)

Specify the oxide names (in the top row) and the percentages of each oxide in each raw material in the table below. Blank values = 0.

When the oxide tolerance multiplier is greater than zero, two additional rows of data are shown in the Raw Materials Composition Table for that oxide, where the raw material oxide tolerances can be entered. The two additional rows show either the minimum and maximum oxide percentage values, or the maximum positive (+) and negative (-) deviations from the nominal oxide percentages in the raw materials. This depends on the **Type of oxide composition tolerances** setting in the **Batch Sheet Options** dialog.

23. LOI %

Calculated loss of ignition for each raw material (in %).

24. Ox Yield

Calculated weights of oxides that remain in glass from each raw material in the selected weight units.

Glass Composition Rows

	Oxides:	SiO2	Al2O3	K2O	Na2O	CaO	MgO
26	Target Composition (Total = 100.00%)	60.00	2.00	2.00	18.00	12.00 ~	
27	Max (+) Deviation % (Default = +2.5% of Target)	1.00	0.10	0.25	0.50	0.30	0.20
	Max (-) Deviation % (Default = -2.5% of Target)	-1.00	-0.10	-0.25	-0.50	-0.30	-0.20
28	Error Weigh. Coef. [0..10]						
29	Oxide Evaporation %						
30	Oxide Saturation %						
31	Calc. Composition (Total = 100.00%)	60.82	1.90	1.75	17.50	11.70 ~	
32	Max Composition %	61.58	2.07	2.00	17.98	12.16 ~	
	Min Composition %	60.06	1.73	1.51	17.03	11.26 ~	
33	Deviation (%)	0.82	-0.10	-0.25	-0.50	-0.30 ~	
34	Max (+) Deviation %	1.58	0.07	0.00	-0.02	0.16 ~	
	Max (-) Deviation %	0.06	-0.27	-0.49	-0.97	-0.74 ~	
35	Ox Group Breakdown (%)					7.81	3.89
36	Max Composition %					8.19	3.97
	Min Composition %					7.50	3.77

25. Oxides

This row repeats oxide names from the top row of the raw material composition table.

26. Target Composition (Total = xxx %)

Specify in % the target composition in glass for each oxide or oxide group in this row.

Leave blank or enter a **Free Floating Oxide** symbol (default is "Free") to leave an oxide as free floating (i.e. has no specific target for its percentage in glass).

Enter a **Oxide Group** symbol (default is "~") to group the oxide with the one on the left. Grouped oxides are treated as one: their individual percentages in glass are added together.

You can view and edit the **Free Floating** and **Grouped** oxide symbols by selecting Global Program Options on the Settings menu and then clicking on the **Symbols** tab.

The total percentage of oxides in the target composition is shown in the row title, for example (Total = 100.00%). The total includes all oxides and groups whose composition is not free floating.

27. Target Composition **Max Value / Max (+) Deviation**
Target Composition **Min Value / Max (-) Deviation**

These two rows contain the target glass composition tolerances. Here you can specify for each oxide the maximum and minimum allowed percentage in glass, or the maximum positive and negative deviations from the target percentage. Leave blank to apply the default Max & Min value / Max (+) & (-)deviation.

You can toggle between using maximum & minimum values and maximum (+) & (-) deviations from the target by selecting Batch Sheet Options on the Settings menu and then clicking on the **Tolerances** tab. There you can also specify default tolerances that will apply to all oxides for which the maximum or minimum value or deviations are not explicitly set, and whether the default tolerances are absolute or relative to the target % of oxide.

The default Max & Min value / Max (+) & (-) deviation are shown in the row titles. For example the following row titles indicate the same ±2.5% relative tolerance:

Max Value % (Default = 102.5% of Target)
Min Value % (Default = 97.5% of Target)

Max (+) Deviation % (Default = +2.5% of Target)
Max (-) Deviation % (Default = -2.5% of Target)

The above **Relative** tolerances mean that if the target an oxide is 60%, then it's maximum allowed percentage is 1.025 x 60 = 61.5% and the minimum allowed percentage is .975 x 60 = 58.5%.

If you select **Absolute** for default tolerances, then the row titles will change to:

Max Value % (Default = Target + 2.5%)
Min Value % (Default = Target - 2.5%)

Max (+) Deviation % (Default = +2.5%)
Max (-) Deviation % (Default = -2.5%)

The above **Absolute** tolerances mean that if the target for an oxide is 60%, then it's maximum allowed percentage is 60 + 2.5 = 62.5 % and the minimum allowed percentage is 60 - 2.5 = 57.5%.

28. Error Weigh. Coef. [0..10]

Specify the error weighing coefficient for each oxide in this row, or leave blank for a default value of 1.

Use values > 1 to reduce the deviation from target composition for an oxide.

Use values < 1 for the opposite effect.

29. Oxide Evaporation %

Specify the oxide evaporation loss in % for each individual oxide in glass, even if it is a member of a group. Leave empty if there is no evaporation of this oxide.

Oxide evaporation loss means that a percentage of the oxide is lost after the batch is melted. Therefore, the loss of ignition for each raw material containing this oxide will increase, as well as the overall loss of ignition.

If the loss of raw material occurs before melting due to carryover, then specify it in the **Carryover Loss %** column.

30. Oxide Saturation %

Specify the maximum percentage of each oxide in glass, regardless of the percentage of the oxide present in the batch. Leave blank in case there is no limit for the maximum percentage of oxide in glass, which is common for majority of oxides.

For example, if the percentage of SO3 in glass is limited to 0.3%, then enter 0.3.

31. Calc. Composition (Total = xxx %)

This row shows the calculated nominal glass composition (in % of each oxide or oxide group). It depends on:

- Calculated batch weights for each raw material (**Batch** column)
- Raw material carryover losses (**Carryover Loss %** column)
- Nominal compositions of all raw materials (**Raw Materials Composition Table**)
- Oxide evaporation losses (**Oxide Evaporation %** row)
- Oxide saturation losses (**Oxide Saturation** % row)

The total percentage of oxides in the calculated glass composition is shown in the row title, for example (Total = 100.00%). The total includes all oxides and groups, including or not including the free floating oxides, which depends on the settings for the **Calculated Composition Total of Oxide %** (found under Batch Sheet Options on the Settings menu in the **Batch** tab.)

32. Calc. Composition **Max Composition %**
Calc. Composition **Min Composition %**

Calculated minimum and maximum percentages of each oxide or oxide group in glass, as determined by the Min/Max Analysis.

33. Deviation (%)

This row shows the deviations (differences) between the calculated and target glass compositions (i.e., target and calculated percentages of each oxide or oxide group). It is based on nominal compositions of all raw materials and zero weighing errors.

34. Deviation **Max (+) Deviation %**
Deviation **Max (-) Deviation %**

These two rows show the maximum positive (+) and negative (-) deviations (differences) between the calculated and target glass compositions, as determined by the Min/Max Analysis.

35. Ox Group Breakdown (%)

This row shows a breakdown of the oxide percentages in the calculated glass composition for individual oxides that are part of a group. It is based on nominal compositions of all raw materials and no weighing errors.

36. Ox Group Breakdown **Max Composition %**
Ox Group Breakdown **Min Composition %**

Calculated minimum and maximum percentages of individual oxides that are part of a group, as determined by the Min/Max Analysis.

Min/Max Analysis

When TriBatch calculates or solves a batch sheet, it determines the nominal glass composition, (in % of each oxide or oxide group), which depends on:

- Calculated batch weights for each raw material (**Batch** column)
- Raw material carryover losses (**Carryover Loss %** column)
- Nominal compositions of all raw materials (**Raw Materials Composition Table**)
- Oxide evaporation losses (**Oxide Evaporation %** row)
- Oxide saturation losses (**Oxide Saturation** % row)

TriBatch can also perform a Min/Max analysis, in which it also calculates the upper and lower limits of the oxide percentages in glass. This is done by calculating the combined effects of the uncertainty in the raw material weights and the uncertainty in the raw material composition.

Min/Max analysis is used to calculate the following glass composition rows in the batch sheet:

- Max Composition %
- Min Composition %
- Max (+) Deviation %
- Max (-) Deviation %

Note that neither of the **Max Composition** and **Min Composition** rows shows a valid calculated glass composition, but a maximum and minimum percentage of each oxide individually (the sum of **Max Composition** row is greater than, and the sum of **Min Composition** row is greater than the **Calc. Composition Total**). In reality, the total percentage of oxides is always 100%, therefore, percentages of some of the oxides will be above the calculated composition while others will be below.

The results of Min/Max analysis depend on:

- Specified maximum weighing errors when adding each raw material to the batch (**Weighing Err.** column)
- Maximum positive (+) and negative (-) oxide percentage deviations from the nominal raw material composition, (**Raw Materials Composition Table**, (+) and (-) tolerance rows)
- Oxide tolerance multiplier (**Ox. Tol. Coeff.** column). This number can be between 0 and 10, with a blank value = 0.
  For each raw material, the maximum positive (+) and negative (-) oxide percentage deviations from the nominal raw material composition given in the **Raw Materials Composition Table** are multiplied by the value of **Ox. Tol. Coeff.** This calculation determines the maximum and minimum oxide percentages for that raw material that are used in the Min/Max analysis.

You can turn the Min/Max analysis on or off by selecting **Calculation** tab in the Batch Sheet Options on the Settings menu and checking or clearing the **Perform min/max analysis** check box.

This command is unavailable in the Lite version of TriBatch.

TriBatch Main Menu

The main TriBatch menu contains the following pull-down menus:

File

Contains commands used to open, save, export and print batch sheets, as well as login as another user and close TriBatch.

Edit

Contains commands used to cut, copy, paste and values to and from TriBatch clipboard.

View

Contains commands used to modify batch sheet layout, highlighting, screen tips, summary and access Excel's view settings.

RawMaterial

Contains commands used to manipulate raw materials in the current batch sheet (insert, delete, move, or change the number of raw materials). Also used to copy selected raw materials from the batch sheet to the current raw material database, and to access the Raw Material Database dialog.

Oxide

Contains commands used to manipulate oxides in the current batch sheet (insert, delete, move, or change the number of oxides).

Calculate

Contains commands used to calculate or solve the batch sheet for minimum standard error or minimum glass cost.

Settings

Contains commands used to access TriBatch dialogs that control various options and settings that apply to TriBatch, the current batch sheet and the raw material database.

Window

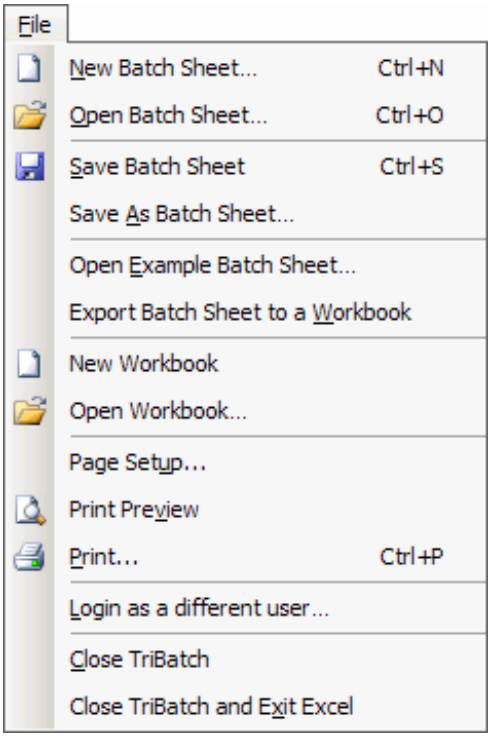
Contains Excel's standard Window pull-down menu.

Help

Contains commands used to access TriBatch and Excel help files. Also contains **About TriBatch** dialog that shows TriBatch version and registration information.

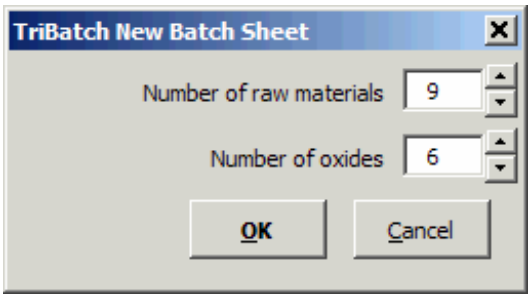
File Menu

Contains commands used to open, save, export and print batch sheets, as well as login as another user and close TriBatch.



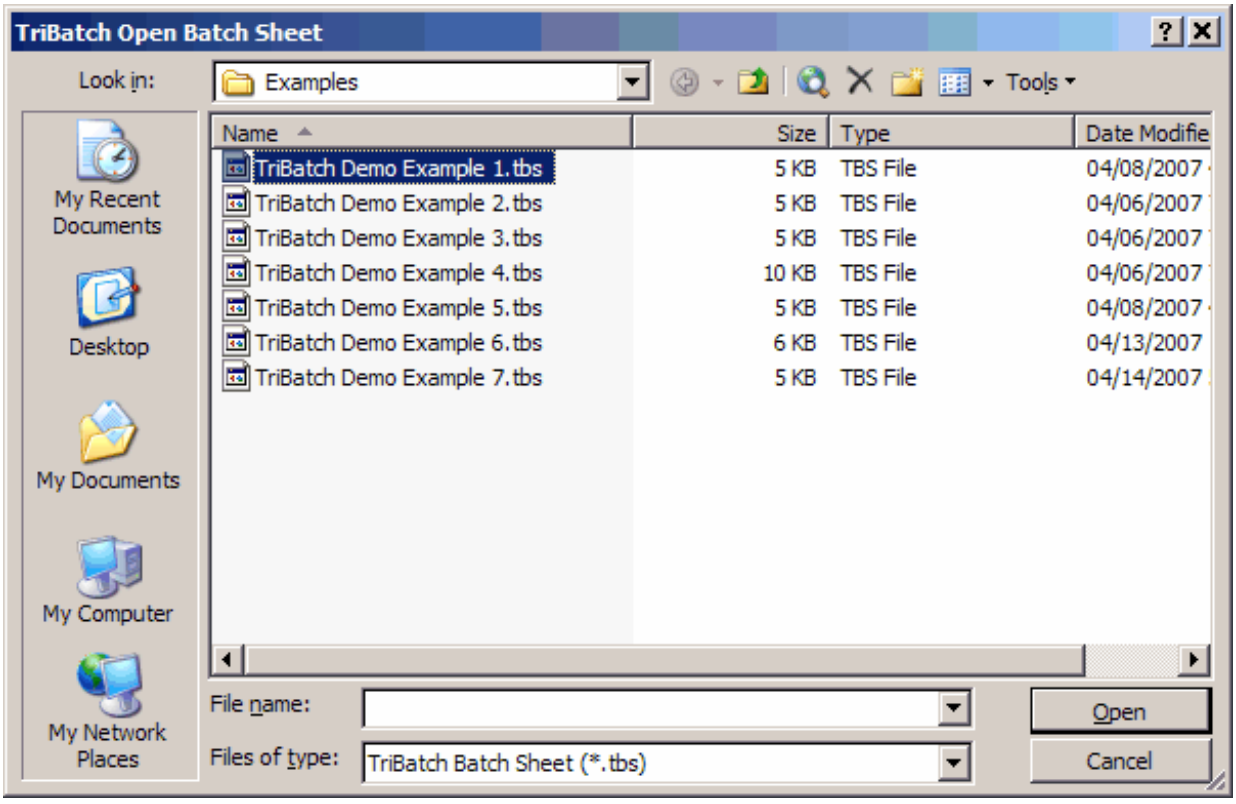
New Batch Sheet...

Displays the **New Batch Sheet** dialog that lets you set the numbers of raw materials and oxides in the new sheet. It then creates a new empty batch sheet.



Open Batch Sheet...

Displays the **Open Batch Sheet** dialog that lets you open a previously saved TriBatch Batch Sheet. The TriBatch batch sheet files have extensions ".tbs".

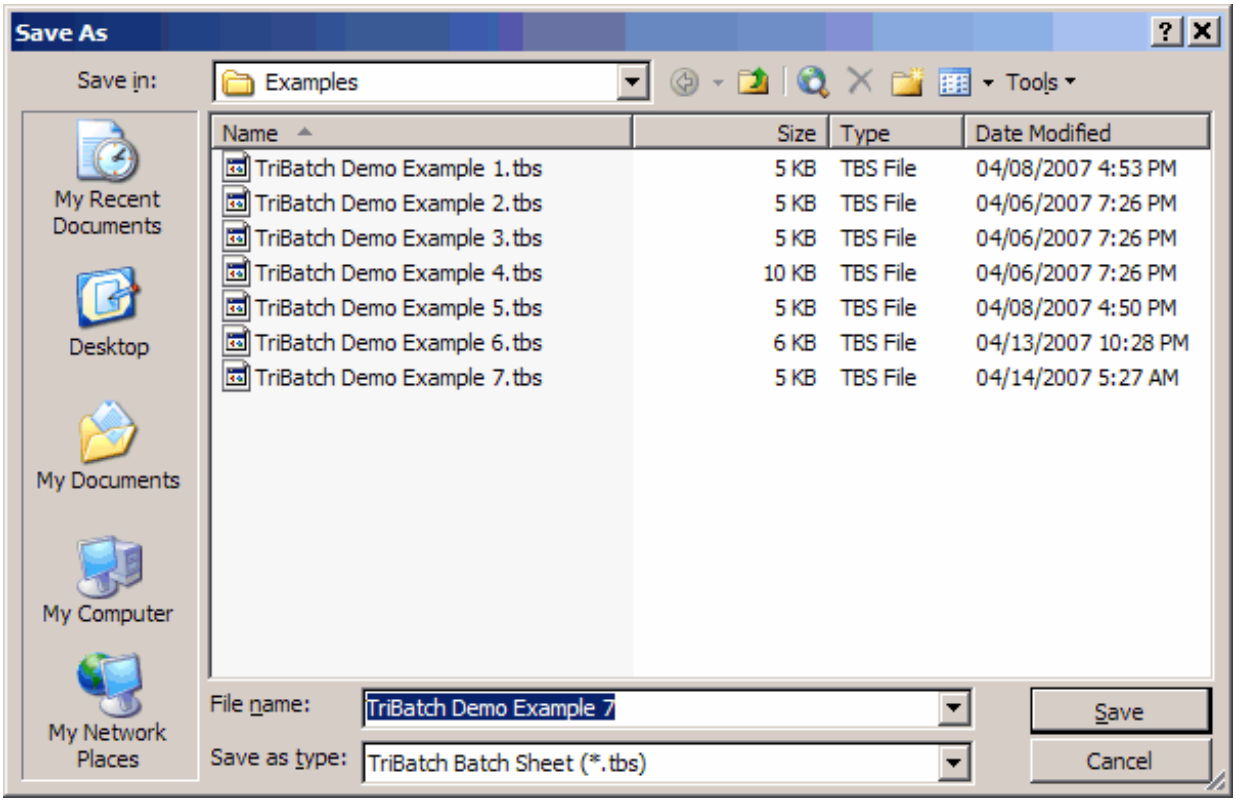


Save Batch Sheet

Saves the current batch sheet to a file. The file name is shown in the **Batch Sheet Name** cell and the extension is ".tbs"

Save As Batch Sheet...

Displays the **Save Batch Sheet** dialog that lets you save the current batch sheet under a different name and/or in a different folder. The TriBatch batch sheet files have extensions ".tbs".



Open Example Batch Sheet...

Displays the **Open Batch Sheet** dialog that lets you open an example batch sheet that was included in the TriBatch software package.

Export Batch Sheet to a Workbook

This command takes a snapshot of the current batch sheet, including all custom formatting, and copies it to a new Excel workbook, with all formulas replaced by values.

This command is useful if you wish to edit use, modify or save the batch sheet data in a way that is not supported inside the TriBatch environment.

When you switch between a TriBatch batch sheet and an Excel workbook the main menu bar and the toolbars are adjusted accordingly.

This command is unavailable in the Lite version of TriBatch.

New Workbook...

Creates a new Excel workbook.

Open Workbook...

Displays Excel's **File Open** dialog that lets you open a previously Excel workbook.

Page Setup...

Displays Excel's **Page Setup** dialog that lets you review and change the print settings used to print batch sheets from within TriBatch.

 **Print Preview**

Displays print preview of the current batch sheet.

 **Print...**

Displays Excel's **Print** dialog that lets you print the current batch sheet.

Login as a different user...

Displays Login dialog that lets log in as a different user. Each user has its own set of default program, batch sheet and raw material database settings.

Close TriBatch

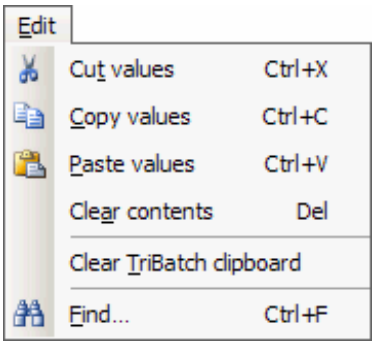
Closes TriBatch and returns to Excel.

Close TriBatch and Exit Excel

Closes TriBatch and also closes Excel.

Edit Menu

Contains commands used to cut, copy, paste and values to and from TriBatch clipboard.



Cut values

Cuts the selected values and places them in TriBatch clipboard.

Copy values

Copies the selected into TriBatch clipboard.

Paste values

Pastes the contents of the TriBatch clipboard into the selected cells. Only the values in the input cells are replaced..

Clear contents

Clears the contents of the selected input cells.

Clear TriBatch clipboard

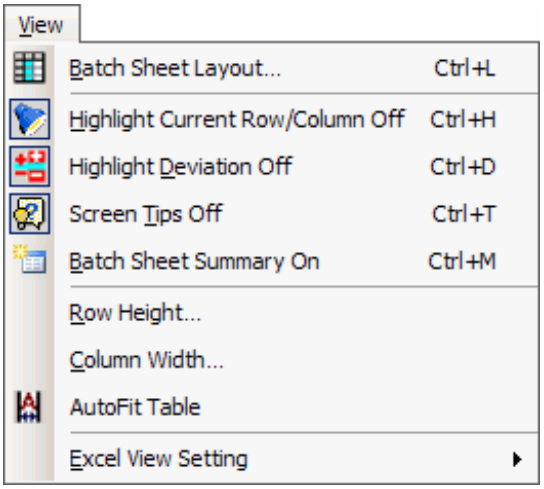
Clears the contents of TriBatch clipboard.

Find

Displays Excel's **Find/Replace** dialog. Note that Replace functionality is disabled within TriBatch.

View Menu

Contains commands used to modify batch sheet layout, highlighting, screen tips, summary and access Excel's view settings.



Batch Sheet Layout…

Displays the Batch Sheet Layout dialog that lets you display or hide rows and columns of the batch sheet, as well as, adjust the column width and the number of decimal places.

Highlight Current Row/Column (On/Off)

Highlights the currently selected row and column. You can further select which types of cells to highlight by selecting Global Program Options on the Settings menu and then clicking on the **Highlighting** tab.

Tip: If this feature slows down your screen updating too much, try using the highlighting for title cells only.

Highlight Deviation (On/Off)

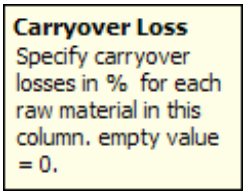
Turns on or off the highlighting of the following result cells:

The **Calculated Composition** and **Deviation** values at a tolerance limit are shown in Blue, while the out of tolerance values are shown in Red.

The raw material weights in the **Batch** column that are equal zero are shown in Blue, while values less than zero are shown in Red.

Screen Tips (On/Off)

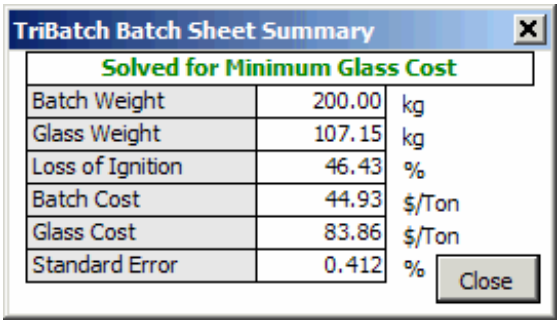
Turns on or off the tip messages that appear when you select any of the row or column titles in the batch sheet. These tips give a short description of the batch sheet data shown the associated cell, row or column. For example, the following tip message will be displayed after a cell in the **Carryover Loss** column header:



Note: The tip message window normally appears next to the selected header cell. However, if you use the mouse to drag it to a different location on the screen, it will remain in that same location for all header cells until you restart Excel.

Batch Sheet Summary (On/Off)

Displays or hides a separate **Batch Sheet Summary** window with the same information as the batch and glass properties cells in the top left corner of the batch sheet (Batch Sheet Status, Batch Weight, Glass Weight, Loss of Ignition, Batch Cost, Glass Cost and Standard Error). Hiding these cells and using the **Batch Sheet Summary** window instead enables you to better utilize the available screen area to display more data rows.



Row Height

Lets you specify the height of the selected rows (in points).

Column Width

Lets you specify the width of the selected columns (in points).

AutoFit Table

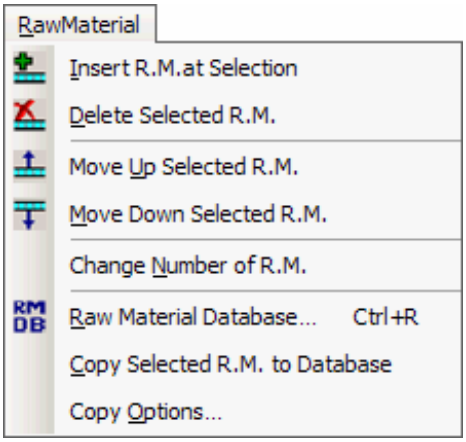
Adjusts widths of all the columns in the batch sheet to fit the content.

Excel View Settings

Displays a sub-menu that lets you access different Excel view functions. See Excel's help for details.

RawMaterial Menu

Contains commands used to manipulate raw materials in the current batch sheet (insert, delete, move, or change the number of raw materials). Also used to copy selected raw materials from the batch sheet to the current raw material database, and to access the Raw Material Database dialog.



Insert R.M. at Selection

Inserts one new raw material row into the batch sheet at the current cursor position. Note that the maximum number of raw materials in a batch sheet is 25.

Delete Selected R.M.

Deletes the selected raw material(s) from the batch sheet. Note that the minimum number of raw materials in a batch sheet is 2.

Move Up Selected R.M.

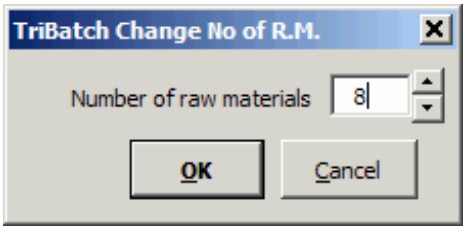
Moves the selected raw material one row up.

Move Down Selected R.M.

Moves the selected raw material one row down.

Change Number of R.M.

Displays the **Change No of RM** dialog. If you enter a number of raw materials that is greater than the current number in the batch sheet, new raw material rows will be added at the bottom of the table. If you enter a number of raw materials that is less than the current number in the batch sheet, a number of raw materials will be deleted from the bottom end of the table.



Raw Material Database…

Displays the Raw Material Database dialog through which you can access and manipulate multiple databases of raw materials and copy the raw materials from the currently open database into the batch sheet.

Copy Selected R.M. to Database

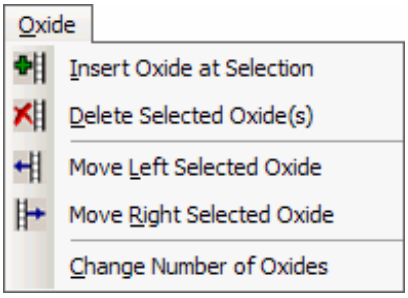
Copies the selected raw materials from the batch sheet to the currently open Raw Material Database.

Copy Options…

Displays the **Batch Sheet -> database** tab of the Raw Material Database Options dialog that lets you choose how the raw materials and oxides will be copied from the batch sheet to the database. The options presented are self explanatory.

Oxide Menu

Contains commands used to manipulate oxides in the current batch sheet (insert, delete, move, or change the number of oxides).



Insert Oxide at Selection

Inserts one new oxide column into the batch sheet at the current cursor position. Note that the maximum number of oxides in a batch sheet is 25.

Delete Selected Oxide(s)

Deletes the selected oxide(s) from the batch sheet. Note that the minimum number of oxides in a batch sheet is 2.

Move Left Selected Oxide

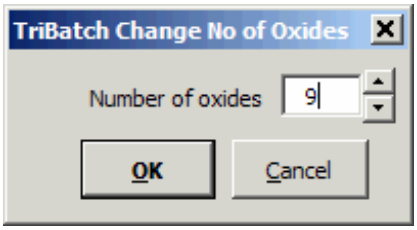
Moves the selected oxide, or the whole group of oxides to which the selected oxide belongs, one column to the left.

Move Right Selected Oxide

Moves the selected oxide, or the whole group of oxides to which the selected oxide belongs, one column to the right.

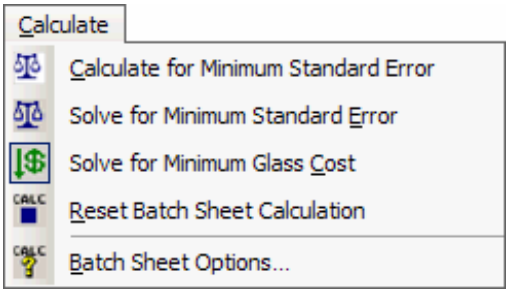
Change Number of Oxides

Displays the **Change No of Oxides** dialog. If you enter a number of oxides that is greater than the current number in the batch sheet, new oxide columns will be added at the right hand side of the table. If you enter a number of oxides that is less than the current number in the batch sheet, a number of oxides will be deleted from the right hand side of the table.



Calculate Menu

Contains commands used to calculate or solve the batch sheet for minimum standard error or minimum glass cost.



Calculate for Minimum Standard Error

Performs batch optimization for closest-to-target glass composition. It determines the required raw material weights that result in a minimum standard error using TriBatch internal math engine. The standard error is calculated from deviations (differences) between the oxide percentages in the calculated glass composition and the target glass composition.

The internal TriBatch math engine can perform batch sheet optimization by taking into account all of the constrains, **except** the tolerances for the percentages of oxides in the glass. For more details, see the **TriBatch Internal Math Engine** chapter beginning on page 66.

Solve for Minimum Standard Error

Performs batch optimization for closest-to-target glass composition. It determines the required raw material weights that result in a minimum standard error using the Solver add-in that is included with Excel. The standard error is calculated from deviations (differences) between the oxide percentages in the calculated glass composition and the target glass composition.

The Solver can perform batch sheet optimization by taking into account all of the constrains, **including** the tolerances for the percentages of oxides in the glass.

This command is unavailable if the Solver add-in is not installed.

Solve for Minimum Glass Cost

Performs batch optimization for minimum glass cost using the Solver add-in. It determines the required raw material weights that result in a minimum cost of batch raw materials required to produce one kg (or any other weight unit) of glass, while keeping the calculated glass composition within the constraints given by the target composition and the tolerances for the percentages of oxides in the glass.

This command is unavailable in the Lite version of TriBatch. It is also unavailable if the Solver add-in is not installed.

Reset Batch Sheet Calculation

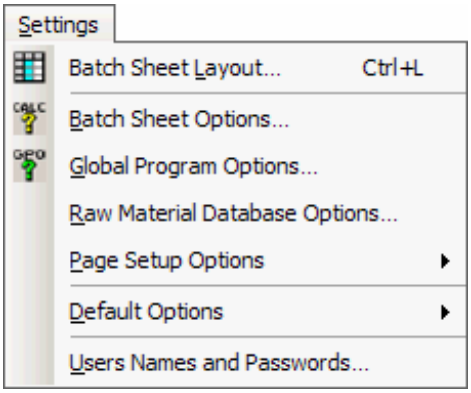
Resets the weights of all raw materials in the batch sheet to zero.

Batch Sheet Options…

Displays the Batch Sheet Options dialog that lets you change various options and settings used in calculating and solving the batch sheet. These options are specific to the current batch sheet and are saved along with the batch sheet.

Settings Menu

Contains commands used to access TriBatch dialogs that control various options and settings that apply to TriBatch, the current batch sheet and the raw material database.



Batch Sheet Layout…

Displays the Batch Sheet Layout dialog that lets you display or hide rows and columns of the batch sheet, as well as, adjust the column width and the number of decimal places.

Batch Sheet Options…

Displays the Batch Sheet Options dialog that lets you change various options and settings used in calculating and solving the batch sheet.

Global Program Options…

Displays the Global Program Options dialog that lets you change various TriBatch options and settings that are not batch sheet specific, but can vary between different users.

Raw Material Database Options…

Displays Raw Material Database Options dialog that lets you choose how the raw materials and oxides will be copied between the batch sheet to the raw material database, as well as the type of tolerances used in the raw material database.

Page Setup Options

Displays a sub-menu that lets you save current page setup options as default (for the currently logged-in user) or restore the default page setup options.

Default Options

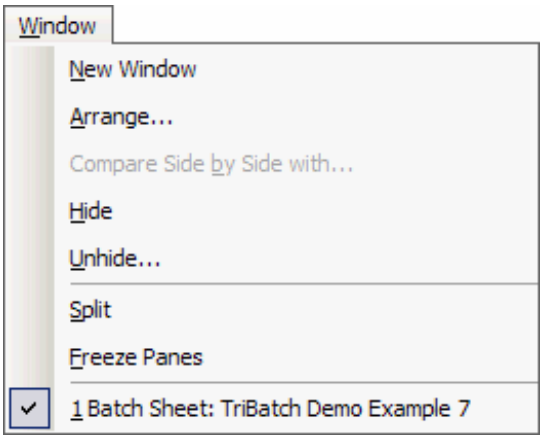
Displays a sub-menu that lets you save all current options as default (for the currently logged-in user) or restore all default options.

Users Names and Passwords…

Displays Users dialog that lets you manage TriBatch users information. This command is only available for users with Access level = 5.

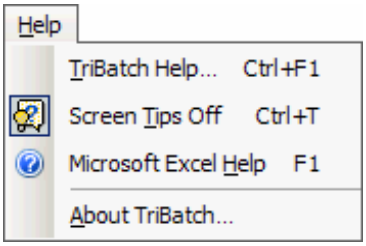
Window Menu

Contains Excel 2003 standard Window pull-down menu. See Excel's help for details.



Help Menu

Contains commands used to access TriBatch and Excel help files. Also contains About TriBatch dialog that shows TriBatch version and registration information.

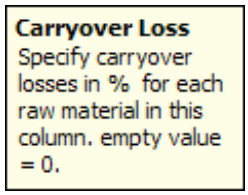


TriBatch Help…

Displays the online help for TriBatch.

Row/Column Heading Tips On/Off

Turns on or off the tip messages that appear when you select any of the row or column titles in the batch sheet. These tips give a short description of the batch sheet data shown the associated cell, row or column. For example, the following tip message will be displayed after a cell in the **Carryover Loss** column header:



Note: The tip message window normally appears next to the selected header cell. However, if you use the mouse to drag it to a different location on the screen, it will remain in that same location for all header cells until you restart Excel.

Microsoft Excel Help

Displays Excel's online help.

About TriBatch…

Displays **About TriBatch** dialog, which contains information on the TriBatch version (Demo, Lite or Pro) and information about the registered user, unless in Demo mode.


About TriBatch
Trimill
Industrial Systems
TriBatch
Glass Batch Calculation and Optimization Program
Version 1.1.0 (2009-04-01)
Copyright © 2007-2009, Trimill Industrial Systems
TriBatch Demo version
info@trimill.com
OK
www.trimill.com

TriBatch Dialogs

TriBatch uses a number of dialogs through which the user can set and change various batch sheet, raw material database and program options and settings. The raw material database itself is accessed through one of the TriBatch dialogs.

Login

Login dialog enables different TriBatch users to login. Each user has separate default settings and options.

Batch Sheet Layout

Batch Sheet Layout dialog lets you display or hide rows and columns of the batch sheet, as well as, adjust the column width and the number of decimal places.

Batch Sheet Options

Batch Sheet Options dialog lets you change various options and settings used in calculating and solving the batch sheet. These options are specific to the current batch sheet and are saved along with the batch sheet.

Global Program Options

Global Program Options dialog lets you change various TriBatch options and settings that are not batch sheet specific, but can vary between different users.

Raw Material Database

Raw Material Database dialog is used to access and manipulate multiple databases of raw materials and copy the raw materials from the currently open database into the batch sheet.

Raw Material Database Options

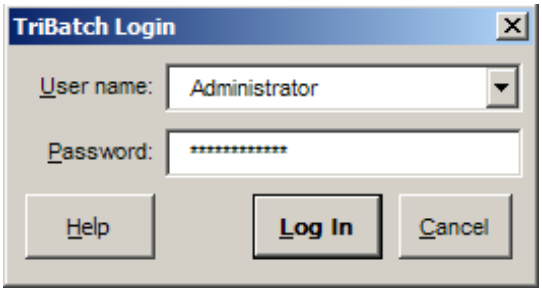
Raw Material Database Options dialog lets you choose how the raw materials and oxides will be copied between the batch sheet to the raw material database, as well as the type of tolerances used in the raw material database.

Users

Users dialog lets you manage TriBatch users information.

Login Dialog

This dialog enables different TriBatch users to login. Each user has separate default settings and options.



User name

Select a user name from this drop-down box.

Password

Enter the password, if any, for the selected user name.

Log In

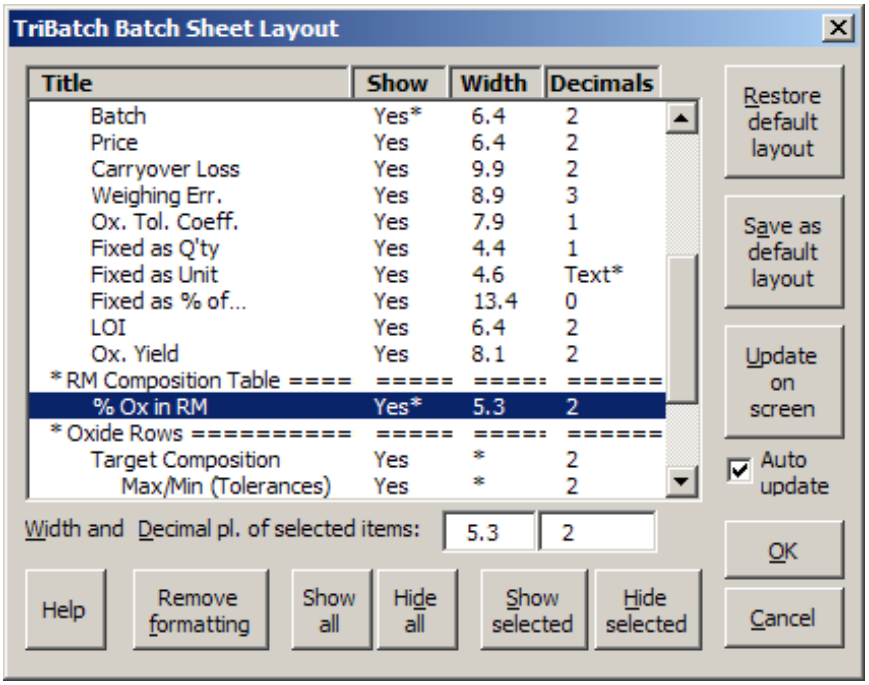
Log into TriBatch and load default Global Program Options for the selected user.

Cancel

Exit without logging into TriBatch.

Batch Sheet Layout Dialog

This dialog lets you display or hide rows and columns of the batch sheet, as well as, adjust the column width and the number of decimal places.



Title | Show | Width | Decimals

This list box contains all elements of a TriBatch Batch Sheet:

- Title = Cell/Row/Column title
- Show = Yes to display the element, blank to hide it
- Width = Width of the element (in points)
- Decimals = Number of decimal places for the element.

The values marked with an asterisk (*) cannot be modified. Multi selection is allowed.

Width. of selected items:

Enter the width (in points) for all selected items for which the width can be modified.

Decimal pl. of selected items:

Enter the number of decimal places (between 0 and 8) for all selected items for which it can be modified.

Remove formatting

Removes custom cell formatting from the entire batch sheet.

Show all

Displays all batch sheet elements.

Hide all

Hides all batch sheet elements that can be hidden.

Show selected

Shows the batch sheet elements selected in the list box.

Hide selected

Hides the batch sheet elements selected in the list box (the ones that can be hidden).

Restore default layout

Restores the default layout saved for the user that is currently logged in.

Save as default layout

Saves the current layout as default for the user that is currently logged in.

Update on screen

Updates the batch sheet layout on the screen to reflect the changes made to it.

Auto update

When checked, automatically updates the batch sheet layout on the screen to reflect the changes made to it.

OK

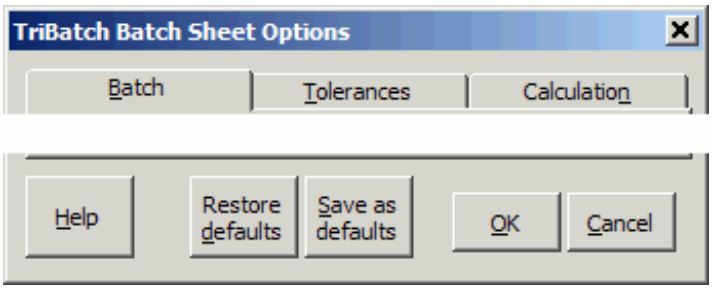
Accepts all of the changes and returns to the batch sheet.

Cancel

Discards all of the changes and returns to the batch sheet.

Batch Sheet Options Dialog

This dialog lets you change various options and settings used in calculating and solving the batch sheet. These options are specific to the current batch sheet and are saved along with the batch sheet.



Restore defaults

Restores the default Batch Sheet Options saved for the user that is currently logged in.

Save as defaults

Saves the current Batch Sheet Options as default for the user that is currently logged in.

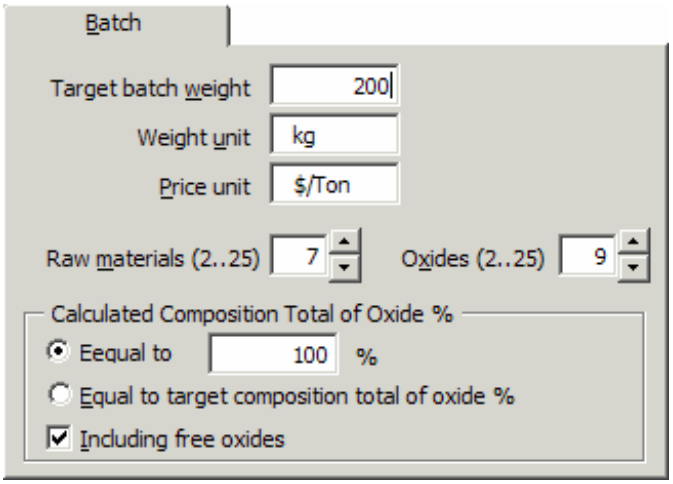
OK

Accepts all of the changes and returns to the batch sheet.

Cancel

Discards all of the changes and returns to the batch sheet.

Batch Tab



Target batch weight

The target for the total of all raw material weights in the batch.

Weight unit

The weight unit used in the batch sheet.

Price unit

The price unit used in the batch sheet.

Raw materials (2..25)

The number of raw materials in the batch sheet.

Oxides (2..25)

The number of oxides in the batch sheet.

Calculated Composition Total of Oxide %

Here you can set the desired % of total oxides in the calculated glass composition.

Equal to

Select this option for fixed percentage (usually 100%) for the total of oxides.

Equal to target composition total of oxide %

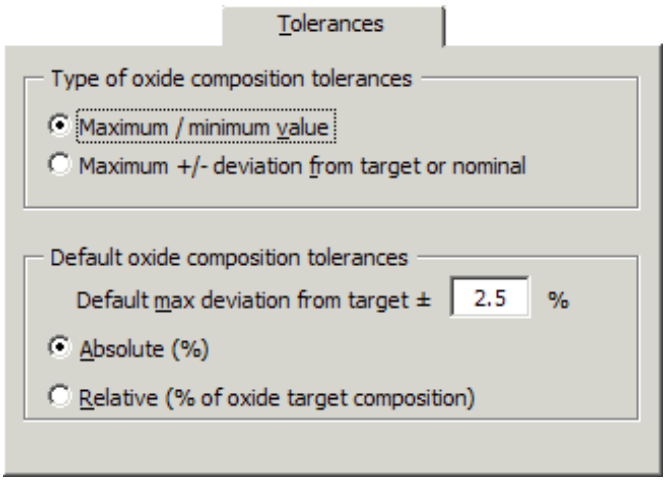
Select this option to use percentage, equal to the target composition total of oxides.

Including free oxides

Check this box to include the free oxides (the ones that have no set target composition) in the calculated composition total oxides.

Tolerances Tab

Here you can set the options for the oxide percentage tolerances used in the batch sheet for the raw material compositions and target glass composition.



Type of oxide composition tolerances

Maximum / minimum value

Select this option to use maximum and minimum values for % oxides when specifying tolerances.

Maximum +/- deviation from target or nominal

Select this option to use maximum positive (+) and negative (-deviations from the nominal percentages (in raw materials) or target percentages (in target glass composition).

Default oxide composition tolerances

Default max deviation from target ±

Specify in % the default ± tolerance, which will take effect if the glass composition tolerances are not explicitly set.

Absolute (%)

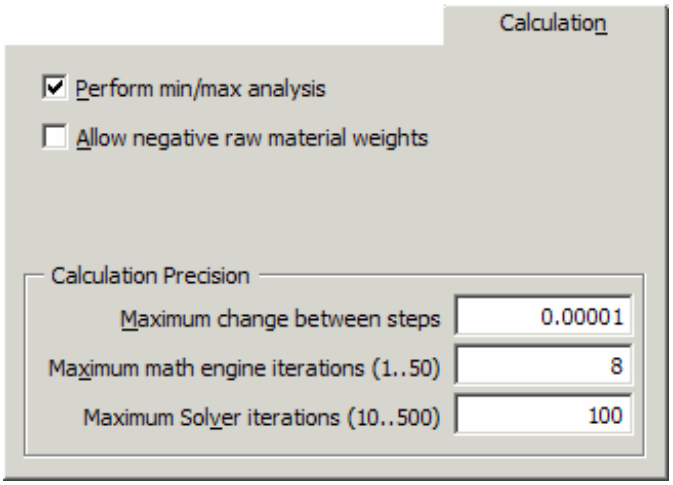
Select this option to use **Absolute** default tolerances. For example, assuming a Default max deviation from target of 2.5%, if the target for an oxide is 60%, then it's maximum allowed percentage is 60 + 2.5 = 62.5 % and the minimum allowed percentage is 60 - 2.5 = 57.5%.

Relative (% of oxide target composition)

Select this option to use **Relative** default tolerances. For example, assuming a Default max deviation from target of 2.5%, if the target an oxide is 60%, then it's maximum allowed percentage is 1.025 x 60 = 61.5% and the minimum allowed percentage is .975 x 60 = 58.5%.

Calculation Tab

Here you can set the calculation options that will be used in calculating and/or solving the batch sheet.



Perform min/max analysis

Check this box to perform Min/Max Analysis using the specified maximum weighing errors when adding each raw material to the batch, as well as the raw material maximum and minimum deviations from nominal composition multiplied by the oxide tolerance multiplier (**Ox. Tol. Coeff.**).

This command is unavailable in the Lite version of TriBatch.

Allow negative raw material weights

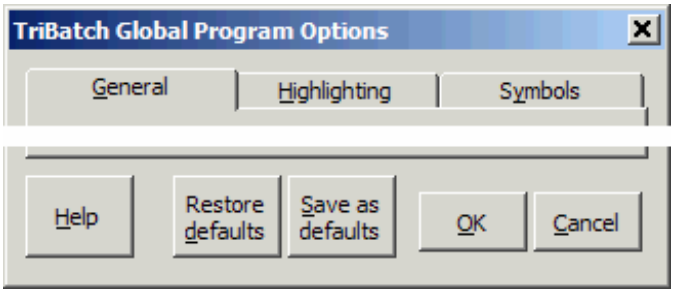
Check this box to allow TriBatch to use negative raw material weights when calculating or solving the batch sheet. It should normally be left unchecked.

Calculation Precision

The three boxes under Calculation Precision set the accuracy and the maximum number of iterations for the TriBatch internal math engine and the Solver. The default values shown above are recommended.

Global Program Options Dialog

This dialog lets you change various TriBatch options and settings that are not batch sheet specific, but can vary between different users.



Restore defaults

Restores the default Global Program Options saved for the user that is currently logged in.

Save as defaults

Saves the current Global Program Options as default for the user that is currently logged in.

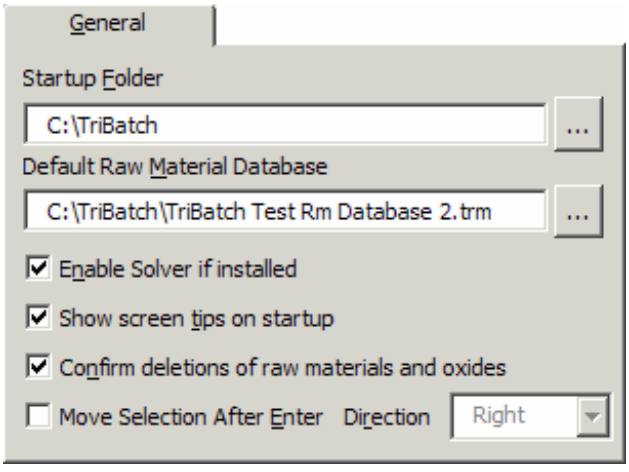
OK

Accepts all of the changes and returns to the batch sheet.

Cancel

Discards all of the changes and returns to the batch sheet.

General Tab



Startup Folder

Specifies the initial folder in which TriBatch will look for batch sheet files.

Default Raw Material Database

Specifies the raw material database that will be initially opened by TriBatch.

Enable Solver if installed

Check this box to enable (use) Solver if it is installed on the system. It should normally be checked.

Show screen tips on startup

Check this box to show screen tips by default.

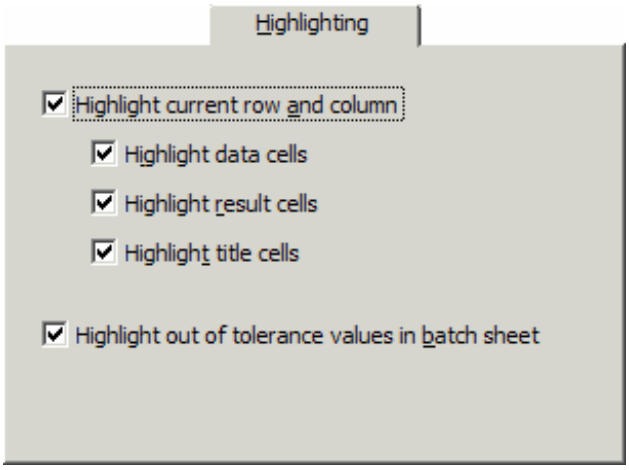
Confirm deletions of raw materials and oxides

Check this box to confirm all deletions of raw materials and oxides from the batch sheet.

Move Selection After Enter, Direction

These two options have the same functionality as they do in Excel.

Highlighting Tab



Highlight current row and column

(Equivalent to **Highlight Current Row/Column** in the View Menu)

Check this box to turn on the highlighting of the currently selected row and column.

Tip: If this feature slows down your screen updating too much, try using the highlighting for title cells only.

Highlight data cells

Check this box to highlight the data (input) cells in the currently selected row and column.

Highlight result cells

Check this box to highlight the result (calculated) cells in the currently selected row and column.

Highlight title cells

Check this box to highlight the row and column title cells in the currently selected row and column.

Highlight out of tolerance values in batch sheet

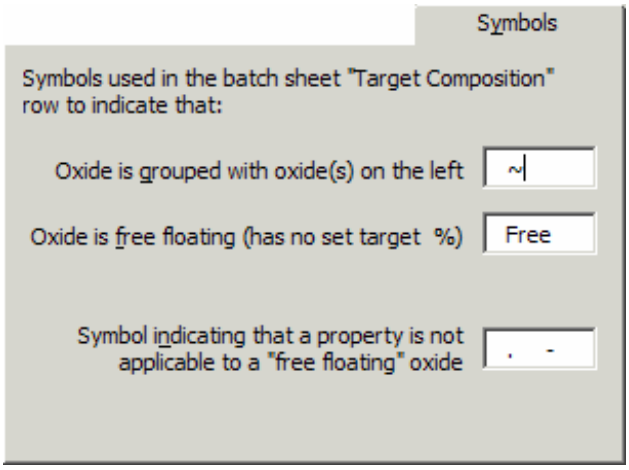
(Equivalent to **Highlight Deviation** in the View Menu)

Check this box to turn on the highlighting of the following result cells:

The **Calculated Composition** and **Deviation** values at a tolerance limit are shown in Blue, while the out of tolerance values are shown in Red.

The raw material weights in the **Batch** column that are equal zero are shown in Blue, while values less than zero are shown in Red.

Symbols Tab



Oxide is grouped with oxide(s) on the left

The symbol used in the batch sheet's **Target Composition** row to indicate that the oxide is grouped with the oxide to the left. Grouped oxides are treated by TriBatch as one when calculating the glass composition. An oxide group can be comprised of two or more oxides that are adjacent to each other in the batch sheet.

Oxide is free floating (has no set target %)

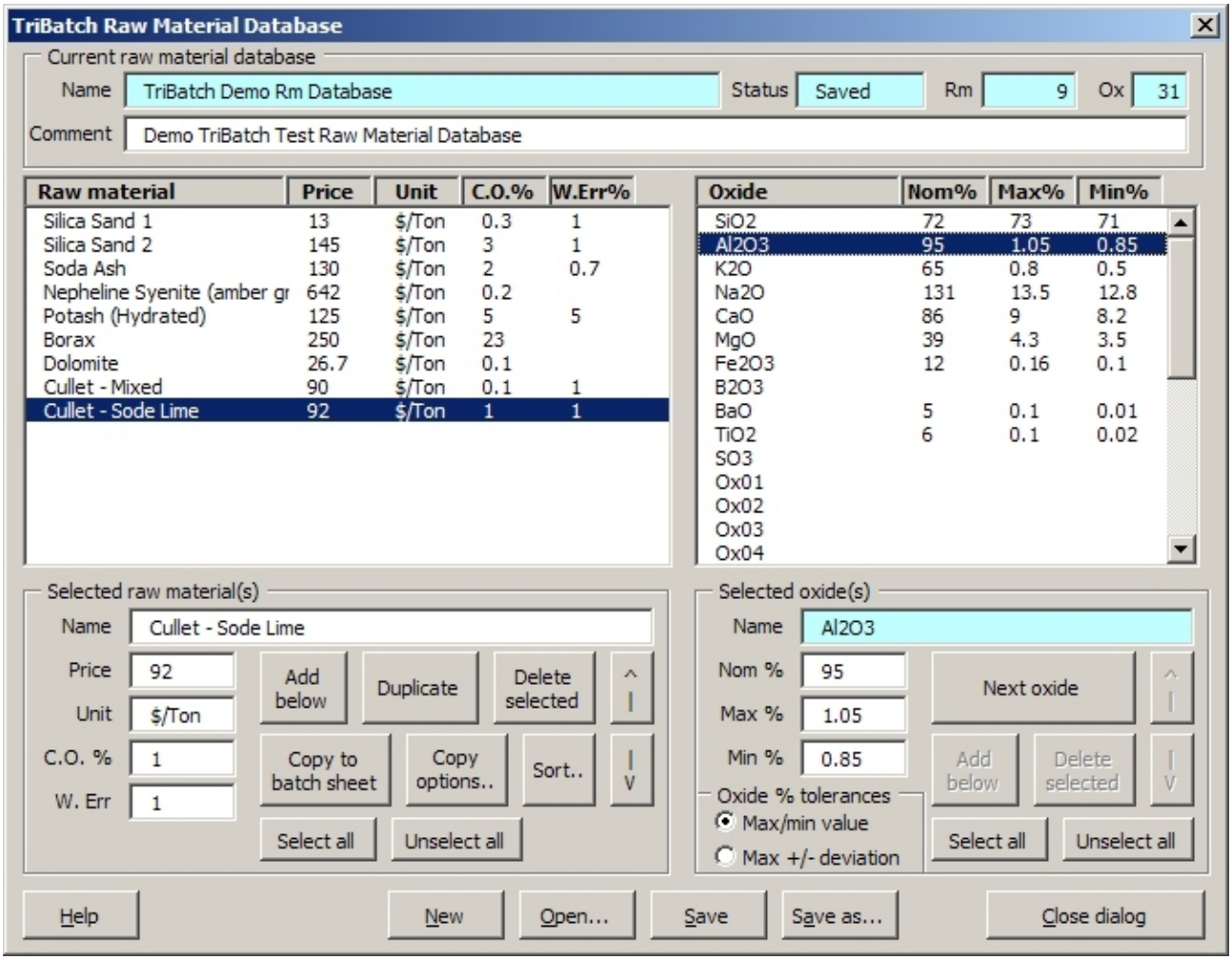
The symbol used in the batch sheet's **Target Composition** row to indicate that the oxide is a "free oxide", meaning that it does not have a specific target percentage in glass.

Symbol indicating that a property is not applicable to a "free floating" oxide

This one is self explanatory.

Raw Material Database Dialog

This dialog is used to access and manipulate multiple databases of raw materials and copy the raw materials from the currently open database into the batch sheet.



Current Raw Material Database Section

Name

Displays the file name of the currently selected Raw Material Database. To change the file name click on the **Save as...** button or rename the file before opening it.

Status

Shows if the current Database has been saved.

Rm

Shows the total number of raw materials in the Database.

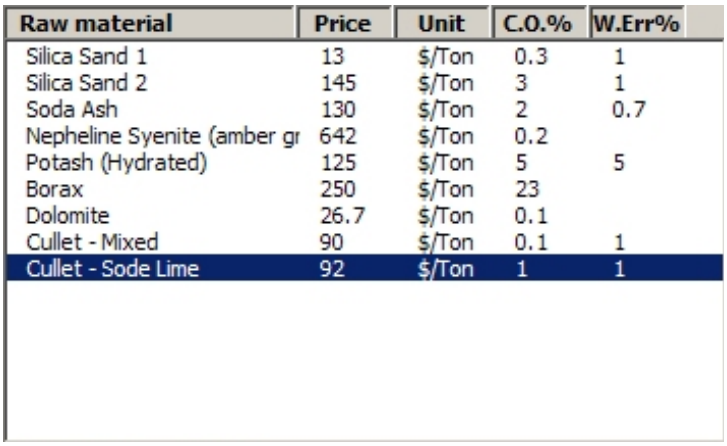
Ox

Shows the total number of oxides in the Database.

Comment

You can type any kind of text here and it will be saved with the Database.

Raw Materials List Box



Raw material	Price	Unit	C.O.%	W.Err%
Silica Sand 1	13	$/Ton	0.3	1
Silica Sand 2	145	$/Ton	3	1
Soda Ash	130	$/Ton	2	0.7
Nepheline Syenite (amber gr	642	$/Ton	0.2	
Potash (Hydrated)	125	$/Ton	5	5
Borax	250	$/Ton	23	
Dolomite	26.7	$/Ton	0.1	
Cullet - Mixed	90	$/Ton	0.1	1
Cullet - Sode Lime	92	$/Ton	1	1

Contains the list of all raw materials in the Database. You can select one or more raw materials in this box and then perform the same action on all the selected raw materials. For example, you can select all the raw materials you wish to copy to the batch sheet and then copy them all at once by clicking on **Copy to batch sheet**.

If more than one raw material is selected in the Raw Materials list box, "~~" will be shown for all the data that is not identical to all the selected raw materials.

Raw Materials list box has the following columns:

Raw Material

Names of the raw materials in the Database. Duplicate raw material names are allowed, but not recommended.

Price

Prices of raw materials. Empty value = 0.

Unit

Price units (for example, $/Ton).

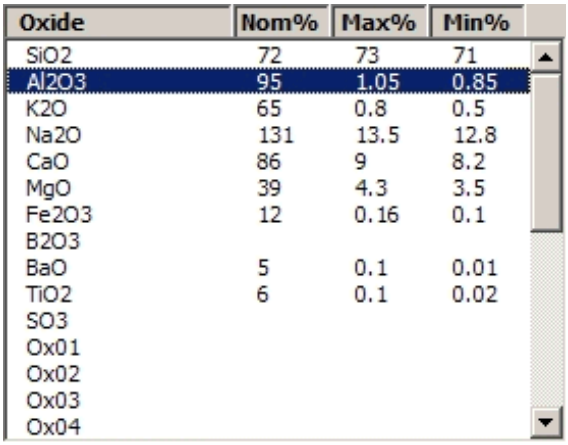
C.O.%

Carryover losses in %. Empty value = 0%.

W.Err

Raw material weighing errors (in units of weight). Empty value = 0.

Oxides List Box



Contains the list of all oxides in the Database. You can select one or more oxides in this box and then perform the same action on all the selected oxides. For example, you can select all oxides and then delete the "~~" from the **Min %** text box. This action will reset all the minimum value or negative deviation of oxide % to default.

If more than one oxide is selected in the Oxides list box, "~~" will be shown for all the data that is not identical to all the selected oxides.

Oxides list box has the following columns:

Oxide

Names of the oxides in the Database. Duplicate oxide names are allowed, but not recommended.

Nom%

Nominal percentages of oxides in the selected raw material(s). Empty value = 0%.

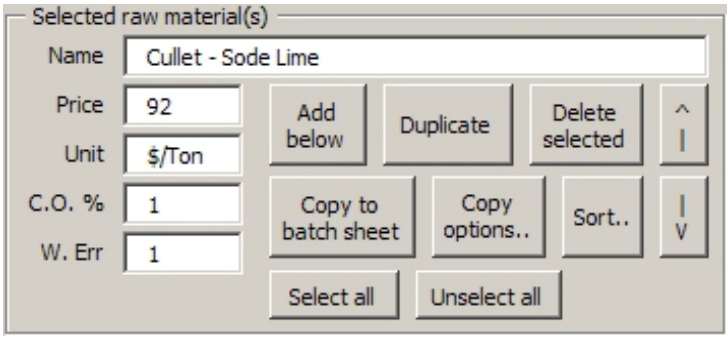
Max%

Either the maximum percentages of oxides, or the maximum positive deviations from the nominal oxide percentages, depending on what is selected under **Oxide % tolerances**. Empty value = default maximum value or positive deviation.

Min%

Either the minimum percentages of oxides, or the maximum negative deviations from the nominal oxide percentages, depending on what is selected under **Oxide % tolerances**. Empty value = default minimum value or negative deviation.

Selected Raw Material(s) Group



Contains text boxes used to edit the properties of the raw material(s) selected in the Raw Materials list box. It also contains command buttons that can be used to manipulate the raw materials in the list box.

Name

Raw material name.

Price

Raw materials price. Empty value = 0.

Unit

Raw material price unit (for example, $/Ton).

C.O.%

Raw material carryover loss in %. Empty value = 0%.

W.Err

Raw material weighing error (in units of weight). Empty value = 0.

Add below

Adds a New Raw Material below the one selected in the list box. If more than one raw material is selected it adds a New Raw Material to the bottom of the list.

Duplicate

Duplicates the selected raw material. Enabled only if one raw material is selected.

Delete selected

Deletes the selected raw material(s) from the database.

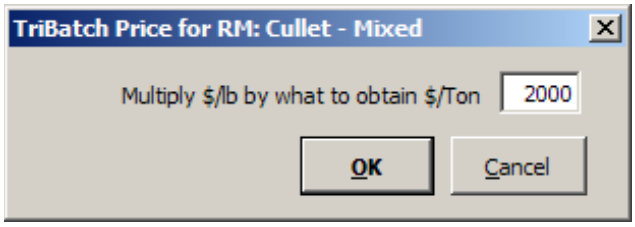
↑ (move up)

Moves the selected raw material up one place in the list. Enabled only if one raw material is selected.

Copy to batch sheet

Copies the selected raw material(s) to the current batch sheet according to the settings specified in the **Raw Material Database Options** dialog.

If the price unit in the database and batch sheet differ, you will be prompted to enter a conversion factor, as shown below.

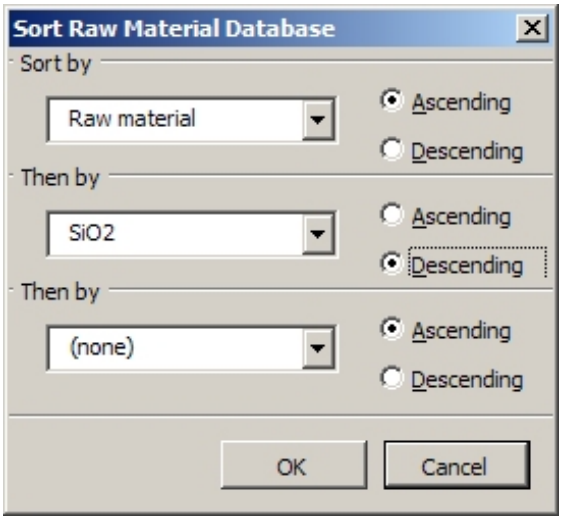


Copy options...

Opens the **Raw Material Database Options** dialog.

Sort...

Opens the **Sort Raw Material Database Options** dialog (shown below) that you can use to sort the raw materials in the Database.



↓ (move down)

Moves the selected raw material down one place in the list. Enabled only if one raw material is selected.

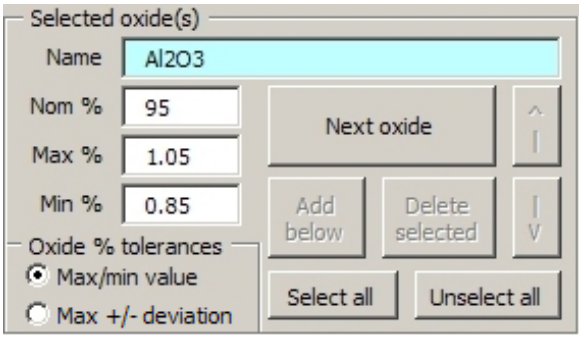
Select all

Selects all of the raw materials in the list.

Unselect all

Un-selects all of the raw materials in the list.

Selected Oxide(s) Group



Contains text boxes used to edit the properties of the oxide(s) selected in the Oxides list box. It also contains command buttons that can be used to manipulate the oxides in the list box.

Name

Oxide name.

Nom %

Nominal percentage of selected oxide(s) in the selected raw material(s). Empty value = 0%.

Max %

Either the maximum percentage selected oxide(s) in the selected raw material(s), or the maximum positive deviation from the nominal oxide percentage, depending on what is selected under **Oxide % tolerances**. Empty value = default maximum value or positive deviation.

Min%

Either the minimum percentage selected oxide(s) in the selected raw material(s), or the maximum negative deviation from the nominal oxide percentage, depending on what is selected under **Oxide % tolerances**. Empty value = default minimum value or negative deviation.

Oxide % tolerances

Lets you choose between **Max/min value** (maximum/minimum percentages of oxides in the raw materials) and **Max +/- deviation** (maximum positive/negative deviations from the nominal oxide percentages).

This setting applies only to the current Raw Material Database and does not have to be the same as the one chosen for the batch sheet.

Every time you toggle between **Max/min value** and **Max +/- deviation** all the tolerances in the Database are updated to reflect the new setting.

Next oxide

Moves the selection in the oxide list box one row down the list. Available only if one oxide is selected.

↑ (move up)

Moves the selected oxide up one place in the list. Enabled only if one oxide and no raw materials are selected.

Add below

Adds a New Oxide below the one selected in the list box. If more than one oxide is selected it adds a New Oxide to the bottom of the list. Available only if no raw material is selected.

Delete selected

Deletes the selected oxide(s) from the database. Available only if no raw material is selected.

↓ (move down)

Moves the selected oxide down one place in the list. Enabled only if one oxide and no raw materials are selected.

Select all

Selects all of the oxides in the list.

Unselect all

Un-selects all of the oxides in the list.

Buttons

Help

Displays the help Raw Material Database topic.

New

Clears the current database.

Open...

Displays an **Open Raw Material Database** dialog. Used to open a previously saved database.

Save

Saves the current Raw Material Database.

Save as...

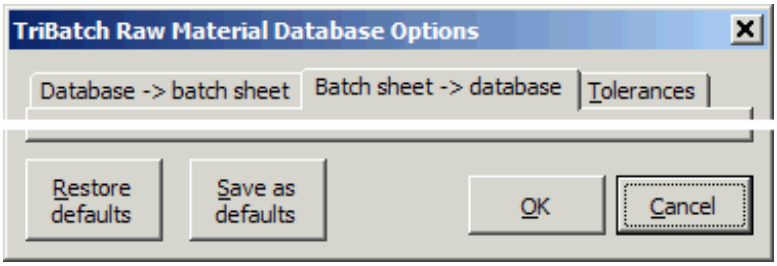
Displays an **Save as** dialog. Used to save the current database under a different name.

Close dialog

Closes the **Raw Material Database** dialog, but leaves the current Database open.

Raw Material Database Options Dialog

This dialog lets you choose how the raw materials and oxides will be copied between the batch sheet to the raw material database, as well as the type of tolerances used in the raw material database.



Restore defaults

Restores the default Raw Material Database options for the user currently logged in.

Save as defaults

Saves the current Raw Material Database options as default for the user currently logged in.

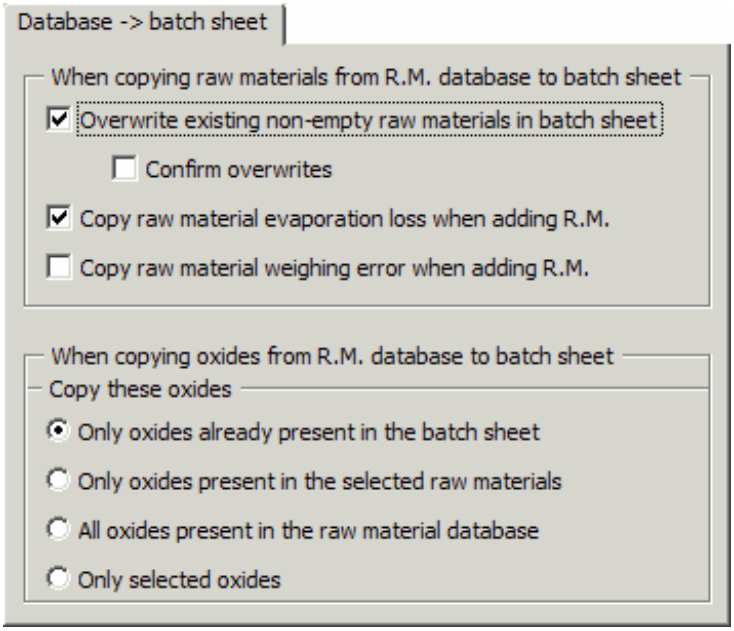
OK

Accepts all of the changes and returns to the batch sheet.

Cancel

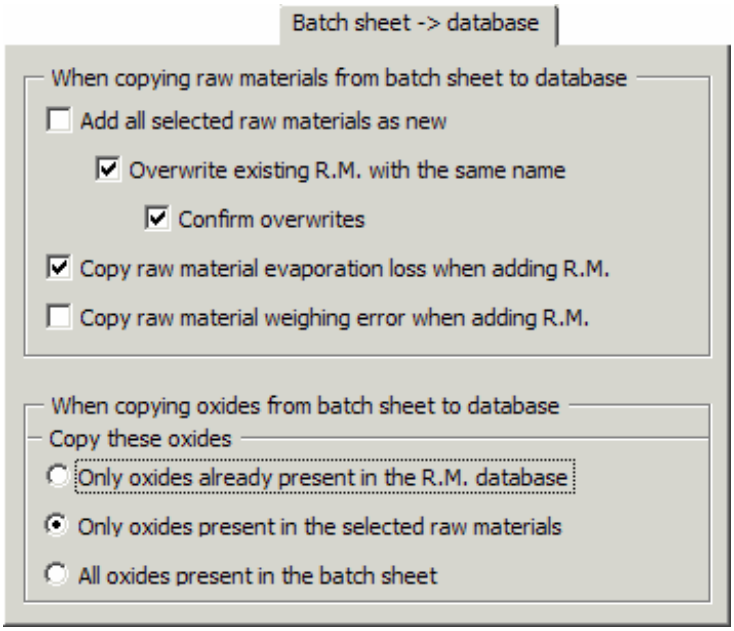
Discards all of the changes and returns to the batch sheet.

Database -> batch sheet Tab



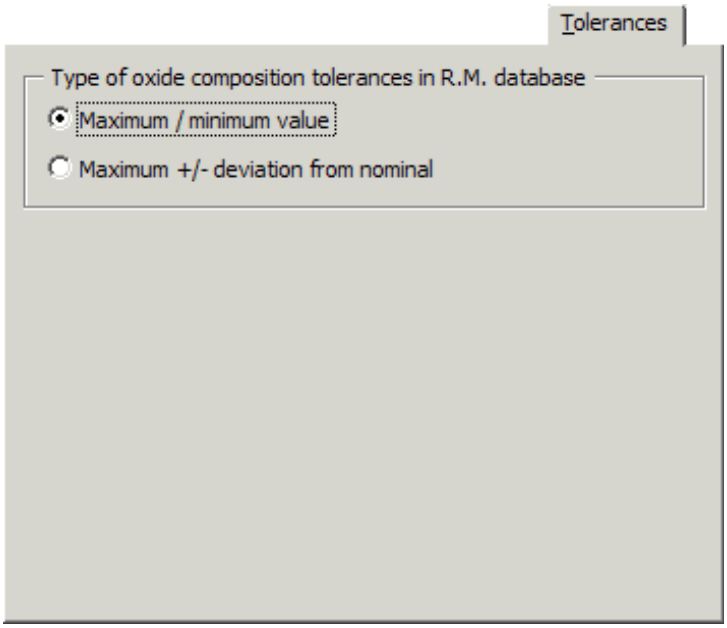
This tab lets you select the options that determine how to copy the selected raw material(s) from the current Raw Material Database to the current batch sheet.

Batch Sheet -> database Tab



This tab lets you select the options that determine how to copy the selected raw material(s) from the current batch sheet to the current Raw Material Database.

Tolerances Tab



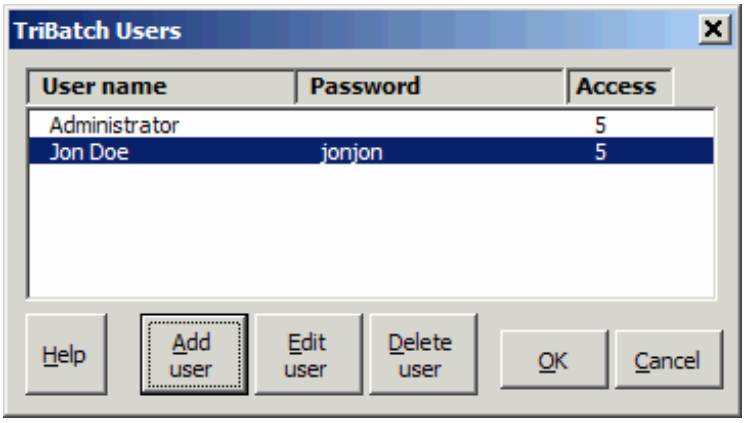
Lets you choose between **Maximum / minimum value** (maximum/minimum percentages of oxides in the raw materials) and **Maximum +/- deviation from nominal** (maximum positive/negative deviations from the nominal oxide percentages).

This setting applies only to the current Raw Material Database and does not have to be the same as the one chosen for the batch sheet.

Every time you toggle between **Maximum / minimum value** and **Maximum +/- deviation from nominal** all the tolerances in the Database are updated to reflect the new setting.

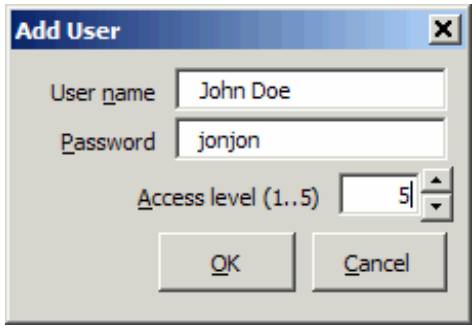
Users Dialog

This dialog lets you manage TriBatch users information. Only a user with Access level = 5 can access this dialog through **Users Names and Passwords…** in the **Settings** menu.



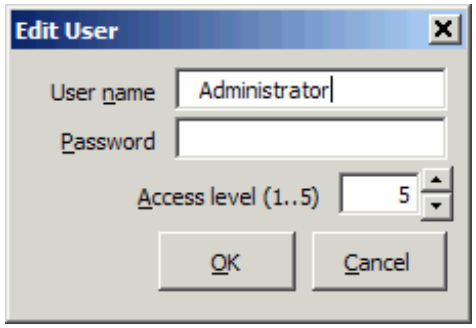
Add user

Displays the **Add User** dialog (see below) through which you can add a new user. When adding a user, you must specify the User Name, Password (can be left blank) and Access level between 1 and 5.



Edit user

Displays the **Edit User** dialog (see below) through which you can edit user information.



Delete user

Deletes the selected user from the list of users. Note that user **Administrator** cannot be deleted.

TriBatch Internal Math Engine

Notation

Symbol	Description
a_{ij}	percentage of oxide or group *i* in raw material *j*, adjusted for over the saturation limit oxides and evaporation losses (*i*=1...*n*; *j*=1...*m*)
a^0_{ij}	input percentage of all individual oxides *i* in raw material *j*, not adjusted (*i*=1...n^i; *j*=1...*m*)
a^1_{ij}	percentage of oxide or group *i* in raw material *j*, not adjusted for over the saturation limit oxides (*i*=1...n^1; *j*=1...*m*)
a^c_{ij}	substitutes for a_{ij} accounting for fixed raw materials (*i*=1...*n*+1; *j*=1...*q*+1)
a^d_{ij}	substitutes for a^c_{ij} in least squares equations (*i*=1...*n*; *j*=1...*q*+1)
a^i_{ij}	percentage of all individual oxides *i* in raw material *j* , adjusted for evaporation (*i*=1...n^i; *j*=1...*m*)
b_{kj}	constants in the final (square) system of equations (*k,j*=1...*q*+1)
b^i_{kj}	elements of matrix $\mathbf{B}^{-1}$ (inverted matrix **B**) (*k,j*=1...*q*+1)
$\mathbf{B}$	square matrix of constants b_{kj} (*k,j*=1...*q*+1)
$\mathbf{B}^{-1}$	inverted matrix **B** – square matrix of constants $\bar{b}_{kj}$ (*k,j*=1...*q*+1)
c_k	constants in the final (square) system of equations (*k*=1...*q*+1)
$\mathbf{C}$	vector of constants c_k (*k*=1...*q*+1)
d^{rm}_j	raw material carryover loss percentage (*j*=1...*m*)
d^{ox}_i	oxide evaporation loss percentage (*i*=1...*n*)
e_i	weighted errors in equations calculating oxide percentages u^c_i (*i*=1...*n*)
E^a	standard error in actual oxide percentages
E^h	standard error in weighted in oxide percentages
E^s	the sum of squares of weighted errors in oxide percentages (e_i)
$E^{x,\max}$	maximum error in raw material quantity
$f^a_{j/k}$	raw material x_j fix ratio relative to raw material weight x_k (*j*=1...p^a)
f^b_j	raw material fix ratio relative to total batch weight (*j*=1...p^b)
f^c_j	raw material absolute fix value (*j*=1... p^c) after adjustment
f^{c0}_j	raw material absolute fix value (*j*=1... p^c) before adjustment
g	number of oxide groups
h_i	error weight coefficients for calculating e_i (*i*=1...*n*)
l_j	individual raw material loss of ignition percentages (*j*=1... *m*)
l^w_j	individual raw material loss of ignition weights (*j*=1... *m*)
m	number of raw materials
n	number of individual oxides + number of oxide groups - oxides with percentages over the saturation limits
n^g_k	number of oxides in each group (*k*=1...*g*)
n^i	number of individual oxides, including those within groups
n^1	number of oxides + groups (including those over the saturation limits)
n^t	number of oxides out of tolerance
n^x	number of oxides exceeding the percentage limits
p	number of fixed raw materials
p^a	number of raw materials fixed relative to other raw material weights

Symbol	Description
p^b	number of raw materials fixed relative to total batch weight
p^c	number of raw materials fixed absolutely
q	number of variables left in the system after removing fixed raw mat. (*m*-*p*)
s_j	specific prices (per unit weight) of raw materials (*j*=1... *m*)
S^b	specific batch cost (per unit weight)
S^g	specific glass cost (per unit weight)
t_i	oxide or group percentage tolerances (*i*=1...n^1)
u_i	target percentages of oxides or groups in glass (*i*=1...*n*), adjusted if required for over the saturation limit oxides
u^i_i	target percentages of all individual oxides in glass (*i*=1...n^i)
u^0_i	target percentages of oxides or groups in glass (*i*=1...n^1) before adjustment for over the saturation limit oxides, before tolerance adjustment
u^1_i	target percentages of individual oxides in glass (*i*=1...n^1) before adjustment for over the saturation limit oxides, after tolerance adjustment
u^{1p}_i	target percentages of oxides or groups in glass (*i*=1...n^1) before adjustment for over the saturation limit oxides, previous tolerance iteration
u^c_i	substitutes for u_i accounting for fixed raw materials (*i*=1...*n*+1)
u^d_i	substitutes for u^c_i in least squares equations (*i*=1...*n*)
u^m_i	maximum percentages of oxides in glass (*i*=1...*n*)
u^w_i	target weights of oxides in glass (*i*=1...*n*)
U	[≈ 100] total target percentage of oxides and groups, adjusted (sum of u_i)
U^0	total target percentage of oxides and groups, not adjusted (sum of u^0_i)
U^{0x}	total of target percentages of out of tolerance oxides, before any adjustments
U^1	total target percentage of oxides and groups, not adjusted (sum of u^1_i)
U^{1x}	total of target percentages of out of tolerance oxides, after adjustments
U^m	total of mnaximum percentages of over the saturation limit oxides
U^x	total of target percentages of over the saturation limit oxides
v_i	calculated percentages of oxides and groups in glass, adjusted (*i*=1...*n*)
v^1_i	calculated percentages of oxides or groups in glass (*i*=1...n^1) after second round of calculation
v^{1p}_i	calculated percentages of oxides or groups in glass (*i*=1...n^1) after second round of calculation, previous tolerance iteration
v^w_i	calculated weights of oxides in glass (*i*=1...*n*)
v^{w1}_i	calculated weights of oxides or groups in glass (*i*=1...n^1) after second round of calculation
V	[≈ 100] total percentage of oxides in glass (sum of v_i)
V^1	total calculated percentage of oxides and groups, not adjusted (sum of v^1_i)
W^b	batch weight (sum of all raw material weights)
W^{b2}	batch weight (sum of all raw material weights) after second round of calculation, after adjustments
W^{bt}	target batch weight
W^g	glass weight (sum of all oxide weights)
W^{g1}	glass weight (sum of all oxide weights) after second round of calculation, before adjustments
W^{g2}	glass weight (sum of all oxide weights) after second round of calculation, after adjustments
W^{gt}	target glass weight
x_j	raw material quantities (*j*=1...*m*)
x^w_j	calculated raw material weights (*j*=1...*m*)

Symbol	Description
x^{w2}_j	calculated raw material weights (j=1...m) after second round of calculation, after adjustments
X	sum of raw material quantities x_j
$\mathbf{X}$	Vector of x_j variables in the final (square) system of equations (j=1...q+1)
y_j	Individual raw material yield percentages (j=1... m)
y^w_j	individual raw material yield weights (j=1... m)
Y	[≤ 100] glass yield percentage (glass weight as percentage of batch weight)

Fundamental System of Equations

The purpose of calculation of batch from target composition is to determine the quantities of individual raw materials in a batch that will produce the composition of glass as close as possible to the target composition.

The number of individual oxides and groups of oxides in the composition (after subtracting those that are over the saturation limits, if any) is *n*. The target composition (adjusted if required for over the saturation limit oxides) is given by percentages of oxides (and groups of oxides) in glass (u_i) where *i*=1...*n*. Note that the oxide groups are treated the same way as the oxides. Unless otherwise specified, the word oxide will be used in further text to denote both individual oxides and oxide groups. Transactions involving oxide groups are explained in 5.1.

The number of raw materials in the batch is *m*. The calculation determines relative quantities of raw material in the batch (x_j) where *j*=1...*m*.

Based on target composition, we can calculate the sum of target percentages (*U*) as:

(1) $$U = \sum_{i=1}^{n} u_i$$

Note that *U* doesn't necessarily amount 100%. The relation between target oxide percentages (u_i) and target oxide weights (u_i^w) is the following:

(2) $$u_i^w = u_i \cdot \frac{W^g}{U} \quad (i = 1...n)$$

where W^g is glass weight, e.i. the weight of glass that will be produced from one batch. We can also calculate the sum of raw material quantities (*X*) as:

(3) $$X = \sum_{j=1}^{m} x_j$$

The relation between raw material quantities (x_j) and raw material weights (x_j^w) is the following:

(4) $$x_j^w = x_j \cdot \frac{W^b}{X} \quad (j = 1...m)$$

where W^b is batch weight:

(4a) $$W^b = \sum_{j=1}^{m} x_j^w$$

The compositions of raw materials (adjusted for over the saturation limit oxides and evaporation losses) are given by a matrix of the percentages of oxides in raw materials (a_{ij}) where *i*=1...*n*; *j*=1...*m*. From the a_{ij} coefficients, we can also calculate raw material yield percentages (y_j) as the percentages of each raw material that are retained in the glass - the balance comes out as loss of ignition (l_j):

(5) $$y_j = \sum_{i=1}^{n} a_{ij} \quad (j = 1...m)$$

(6) $$l_j = 100 - y_j \quad (j = 1...m)$$

We can write the fundamental system of equations for batch calculation in "batch from target composition" mode, where the quantities of raw materials (x_i) are mutually independent and there are no restrictions put on any of them. The system of equations is:

(7)
$$\begin{aligned}
&a_{11}x_1 + a_{12}x_2 + \cdots + a_{1j}x_j + \cdots + a_{1m}x_m \approx u_1 \\
&a_{21}x_1 + a_{22}x_2 + \cdots + a_{2j}x_j + \cdots + a_{2m}x_m \approx u_2 \\
&\quad\vdots \qquad\qquad\quad \vdots \qquad\qquad \vdots \\
&a_{i1}x_1 + a_{i2}x_2 + \cdots + a_{ij}x_j + \cdots + a_{im}x_m \approx u_i \\
&\quad\vdots \qquad\qquad\quad \vdots \qquad\qquad \vdots \\
&a_{n1}x_1 + a_{n2}x_2 + \cdots + a_{nj}x_j + \cdots + a_{nm}x_m \approx u_n
\end{aligned}$$

where a_{ij} (i=1...n; j=1...m) and u_i (i=1...n) are known constants. In general case, the simultaneous equations in the system (7) can only be approximately satisfied, thus the use of "≈" instead of equal signs. Solving this system will yield unknown raw material quantities x_j (j=1...m) which produce the minimum error in glass composition from the target composition given by u_i (i=1...n). Also, after solving the system (7), we can use it to calculate the glass composition v_i (i=1...n) that will be obtained from the calculated batch x_j (j=1...m) and which in general case will differ from the target composition given by u_i (i=1...n):

(7a)
$$\begin{aligned}
&a_{11}x_1 + a_{12}x_2 + \cdots + a_{1j}x_j + \cdots + a_{1m}x_m = v_1 \\
&a_{21}x_1 + a_{22}x_2 + \cdots + a_{2j}x_j + \cdots + a_{2m}x_m = v_2 \\
&\quad\vdots \qquad\qquad\quad \vdots \qquad\qquad \vdots \\
&a_{i1}x_1 + a_{i2}x_2 + \cdots + a_{ij}x_j + \cdots + a_{im}x_m = v_i \\
&\quad\vdots \qquad\qquad\quad \vdots \qquad\qquad \vdots \\
&a_{n1}x_1 + a_{n2}x_2 + \cdots + a_{nj}x_j + \cdots + a_{nm}x_m = v_n
\end{aligned}$$

Based on calculated composition, we can obtain the total percentage of oxides in glass (V) as:

(7b) $$V = \sum_{i=1}^{n} v_i$$

In order to simplify further consideration, we will impose an additional requirement on the system as $V = U$ (the total calculated percentage of oxides in glass equals the total target percentage of oxides in glass). By adding all the equations in the systems (7) and (7a), and taking into account (1) and (7b), we can write:

(8) $$U = V = \sum_{j=1}^{m} y_j x_j = \sum_{i=1}^{n} u_i = \sum_{i=1}^{n} v_i$$

We can now define a new variable called glass yield (*Y*) as:

$$(9) \qquad Y = \frac{V}{X} = \frac{U}{X} = \frac{\sum_{i=1}^{n} v_i}{\sum_{j=1}^{m} x_j} = \frac{\sum_{i=1}^{n} u_i}{\sum_{j=1}^{m} x_j} = \frac{\sum_{j=1}^{m} y_j x_j}{\sum_{j=1}^{m} x_j}$$

When dealing with batch weight (W^b) and glass weight (W^g), glass yield can also be defined as:

$$(10) \qquad Y = \frac{W^g}{W^b} \cdot 100 = \frac{\sum_{i=1}^{n} u_i^w}{\sum_{j=1}^{m} x_j^w} \cdot 100 = \frac{\sum_{j=1}^{m} y_j x_j^w}{\sum_{j=1}^{m} x_j^w}$$

From the above equations it follows that $Y \leq 100$. Also, based on (9) and (10), we can write:

$$(11) \qquad \frac{X}{W^b} = \frac{U}{100 \cdot W^g}$$

In case when $n = m$, the system (7) is a fully determined system of linear equations and there exists one exact solution for each $x_1 \ldots x_m$; also, $v_i = u_i$ for i=1...n. In a more general case where $n > m$ (more equations than variables), the equations in system (7) usually cannot be all satisfied at the same time. This means that the calculated glass composition (given by $v_1 \ldots v_n$) will be different from the target composition (given by $u_1 \ldots u_n$). The calculation in case ($n > m$) is performed by applying a variation of the least squares method that will be discussed later.

For the calculation to be performed, we must first prescribe either a target batch weight (W^{bt}) or a target glass weight (W^{gt}). Only one of these two is given. Depending on which weight is prescribed, we will can distinguish between two different calculation cases.

In **case b** the target batch weight (W^{bt}) is given, so we can write:

(11a) $W^b = W^{bt}$

In **case g**, the target glass weight (W^{gt}) is given:

(11b) $W^g = W^{gt}$

At certain points the calculation takes a different course depending on the case (**b** or **g**) being used. All such points will be addressed in the following paragraphs.

Fixed Raw Materials

Some raw material weights (x_j^w) can be fixed (dependent) in one of the following ways:

a) as a percentage of another raw material weight
b) as a percentage of the batch weight
c) as a given absolute weight.

One or more raw materials in the batch sheet can be fixed in any of the above mentioned ways and almost any combination of fixes is allowed.

Raw Material Fixed Relative to Another Raw Material

Suppose that it is required that a raw material weight x_s^w be fixed relative to the weight of another raw material, say x_r^w, with a ratio of $f_{s/r}^a$:

(12) $$x_s^w = f_{s/r}^a \cdot x_r^w$$

Referring back to (4), the same relation can also be written in terms of raw material quantities x_j:

(13) $$x_s = f_{s/r}^a \cdot x_r$$

By substituting (13) into the system of equations (7) we obtain:

(14)
$$\begin{array}{l}
a_{11}x_1 + a_{12}x_2 + ... + \left(a_{1r} + a_{1s} f_{s/r}^a\right)x_r + ... + 0 \cdot x_s + ... + a_{1m}x_m \approx u_1 \\
a_{21}x_1 + a_{22}x_2 + ... + \left(a_{2r} + a_{2s} f_{s/r}^a\right)x_r + ... + 0 \cdot x_s + ... + a_{2m}x_m \approx u_2 \\
\quad\vdots \qquad\quad \vdots \qquad\quad \vdots \qquad\quad \vdots \qquad\quad \vdots \\
a_{i1}x_1 + a_{i2}x_2 + ... + \left(a_{ir} + a_{is} f_{s/r}^a\right)x_r + ... + 0 \cdot x_s + ... + a_{im}x_m \approx u_i \\
\quad\vdots \qquad\quad \vdots \qquad\quad \vdots \qquad\quad \vdots \qquad\quad \vdots \\
a_{n1}x_1 + a_{n2}x_2 + ... + \left(a_{mr} + a_{ms} f_{s/r}^a\right)x_r + ... + 0 \cdot x_s + ... + a_{nm}x_m \approx u_n
\end{array}$$

We can conclude that fixing a raw material weight relative to another raw material, as in (12), transforms the system of equations (7) into (14), where system (14) contains one variable less than system (7). Variable x_s (raw material quantity) is eliminated from the main system of equations and can be calculated at the end from equation (13).

Raw Material Fixed Relative to Total of Raw Material Quantities

Suppose that the weight of raw material x_t^w is fixed relative to the batch weight W^b with a ratio of f_t^b:

(15) $$x_t^w = f_t^b W^b$$

From (15) and (4) it follows that the raw material quantity (x_t) should fulfill the following equation:

(16) $$x_t = f_t^b X$$

In order to incorporate the condition described by (16) into the system of equations (7), we will first enlarge the system (7) to include the equation giving the total of raw material quantities (3) as the last equation of the system:

$$
\begin{aligned}
&a_{11}x_1 + a_{12}x_2 + \ldots + a_{1j}x_j + \ldots + a_{1m}x_m + a_{1,m+1}X \approx u_1 \\
&a_{21}x_1 + a_{22}x_2 + \ldots + a_{2j}x_j + \ldots + a_{2m}x_m + a_{2,m+1}X \approx u_2 \\
&\quad\vdots \qquad\quad \vdots \qquad\quad \vdots \\
&a_{i1}x_1 + a_{i2}x_2 + \ldots + a_{ij}x_j + \ldots + a_{im}x_m + a_{i,m+1}X \approx u_i \\
&\quad\vdots \qquad\quad \vdots \qquad\quad \vdots \\
&a_{n1}x_1 + a_{n2}x_2 + \ldots + a_{nj}x_j + \ldots + a_{nm}x_m + a_{n,m+1}X \approx u_n \\
&a_{n+1,1}x_1 + a_{n+1,2}x_2 + \ldots + a_{n+1,j}x_j + \ldots + a_{n+1,m}x_m + a_{n+1,m+1}X = u_{n+1}
\end{aligned}
\tag{17}
$$

where:

(17a) $a_{i,m+1} = 0 \quad (i = 1 \ldots n)$

(17b) $a_{n+1,j} = 1 \quad (j = 1 \ldots m)$

(17c) $a_{n+1,m+1} = -1$

(17d) $u_{n+1} = 0$

Now, by substituting (16) into the system of equations (17) we obtain:

$$
\begin{aligned}
&a_{11}x_1 + a_{12}x_2 + \ldots + 0 \cdot x_t + \ldots + a_{1m}x_m + \left(a_{1,m+1} + a_{1t}f_t^b\right)X \approx u_1 \\
&a_{21}x_1 + a_{22}x_2 + \ldots + 0 \cdot x_t + \ldots + a_{2m}x_m + \left(a_{2,m+1} + a_{2t}f_t^b\right)X \approx u_2 \\
&\quad\vdots \qquad\quad \vdots \qquad\quad \vdots \qquad\quad \vdots \\
&a_{i1}x_1 + a_{i2}x_2 + \ldots + 0 \cdot x_t + \ldots + a_{im}x_m + \left(a_{i,m+1} + a_{it}f_t^b\right)X \approx u_i \\
&\quad\vdots \qquad\quad \vdots \qquad\quad \vdots \qquad\quad \vdots \\
&a_{n1}x_1 + a_{n2}x_2 + \ldots + 0 \cdot x_t + \ldots + a_{nm}x_m + \left(a_{n,m+1} + a_{nt}f_t^b\right)X \approx u_n \\
&a_{n+1,1}x_1 + a_{n+1,2}x_2 + \ldots + 0 \cdot x_t + \ldots + a_{n+1,m}x_m + \left(a_{n+1,m+1} + a_{n+1,t}f_t^b\right)X = u_{n+1}
\end{aligned}
\tag{18}
$$

In a similar way as in section 2.1, fixing a raw material weight relative to batch weight, as in (15), transforms the system of equations (17) into (18), which contains one variable less than system (17), since variable x_t is eliminated from the system. The only difference when compared to 2.1 is that in this case the system is expanded by one more variable (X) and one more equation (n+1).

Raw Material Fixed Absolutely

Suppose that a raw material weight x_u^w is fixed in absolute terms and equal to f_u^c:

(19) $x_u^w = f_u^c$

By substituting x_u^w from (4) into (19), we can write:

(20) $x_u = f_u^c \cdot \dfrac{X}{W^b}$

Note that, by taking into account (11), we can also express relation (20) as:

(21) $$x_u = f_u^c \cdot \frac{U}{100 \cdot W^g}$$

Since only one of the weights is known at this point ($W^b = W^{bt}$ in **case b** or $W^g = W^{gt}$ in **case g**), we will use equation (20) in **case b** and equation (21) in **case g**.

In **case b**, substituting (20) into (17) will produce:

$$a_{11}x_1 + a_{12}x_2 + \ldots + 0 \cdot x_u + \ldots + a_{1m}x_m + \left(a_{1,m+1} + a_{1u}\frac{f_u^c}{W^b}\right)X \approx u_1$$

$$a_{21}x_1 + a_{22}x_2 + \ldots + 0 \cdot x_u + \ldots + a_{2m}x_m + \left(a_{2,m+1} + a_{2u}\frac{f_u^c}{W^b}\right)X \approx u_2$$

$$\vdots \qquad \vdots \qquad \vdots \qquad \vdots$$

(22) $$a_{i1}x_1 + a_{i2}x_2 + \ldots + 0 \cdot x_u + \ldots + a_{im}x_m + \left(a_{i,m+1} + a_{iu}\frac{f_u^c}{W^b}\right)X \approx u_i$$

$$\vdots \qquad \vdots \qquad \vdots \qquad \vdots$$

$$a_{n1}x_1 + a_{n2}x_2 + \ldots + 0 \cdot x_u + \ldots + a_{nm}x_m + \left(a_{n,m+1} + a_{nu}\frac{f_u^c}{W^b}\right)X \approx u_n$$

$$a_{n+1,1}x_1 + a_{n+1,2}x_2 + \ldots + 0 \cdot x_u + \ldots + a_{n+1,m}x_m + \left(a_{n,+1m+1} + a_{n+1,u}\frac{f_u^c}{W^b}\right)X = u_{n+1}$$

In **case g**, substituting (21) into (7) will produce:

$$a_{11}x_1 + a_{12}x_2 + \ldots + 0 \cdot x_u + \ldots + a_{1m}x_m + a_{1,m+1}X = u_1 - a_{1u}\frac{f_u^c \cdot U}{100 \cdot W^g}$$

$$a_{21}x_1 + a_{22}x_2 + \ldots + 0 \cdot x_u + \ldots + a_{2m}x_m + a_{2,m+1}X \approx u_2 - a_{2u}\frac{f_u^c \cdot U}{100 \cdot W^g}$$

$$\vdots \qquad \vdots \qquad \vdots \qquad \vdots$$

(23) $$a_{i1}x_1 + a_{i2}x_2 + \ldots + 0 \cdot x_u + \ldots + a_{im}x_m + a_{i,m+1}X \approx u_i - a_{iu}\frac{f_u^c \cdot U}{100 \cdot W^g}$$

$$\vdots \qquad \vdots \qquad \vdots \qquad \vdots$$

$$a_{n1}x_1 + a_{n2}x_2 + \ldots + 0 \cdot x_u + \ldots + a_{nm}x_m + a_{n,m+1}X \approx u_n - a_{nu}\frac{f_u^c \cdot U}{100 \cdot W^g}$$

$$a_{n+1,1}x_1 + a_{n+1,2}x_2 + \ldots + 0 \cdot x_u + \ldots + a_{n+1,m}x_m + a_{n+1,m+1}X = u_{n+1} - a_{n+1,u}\frac{f_u^c \cdot U}{100 \cdot W^g}$$

Note that in both systems (22) and (23), variable x_u is eliminated.

General Case of Raw Material Fixes

Suppose that we have raw material weight x^w_s fixed relative to x^w_r and x^w_t fixed relative to x^w_s. Next x^w_u and x^w_v are fixed relative to batch weight W^b. Also, x^w_w and x^w_x are fixed

relative to x^w_v and x^w_y is fixed relative to x^w_x. Finally, x^w_z is fixed absolutely. According to (12), (15) and (19):

$$
\begin{aligned}
&x_s^w = f_{s/r}^a \cdot x_r^w; \qquad x_t^w = f_{t/s}^a \cdot x_s^w; \\
&x_u^w = f_u^b \cdot W^b; \qquad x_v^w = f_v^b \cdot W^b; \\
&x_w^w = f_{w/v}^a \cdot x_v; \qquad x_x^w = f_{x/v}^a \cdot x_v^w; \qquad x_y^w = f_{y/x}^a \cdot x_x^w; \\
&x_z^w = f_w^c
\end{aligned} \tag{24}
$$

Taking into account (13), (16), (20) and (21), the above equations can be transformed into:

$$
\begin{aligned}
&x_s = f_{s/r}^a \cdot x_r; \qquad x_t = f_{t/s}^a \cdot x_s; \\
&x_u = f_u^b \cdot X; \qquad x_v = f_v^b \cdot X; \\
&x_w = f_{w/v}^a \cdot x_v; \qquad x_x = f_{x/v}^a \cdot x_v; \qquad x_y = f_{y/x}^a \cdot x_x; \\
&x_z = f_w^c \frac{X}{W^b} \quad \text{(case b)}; \qquad x_z = f_w^c \frac{U}{100 \cdot W^g} \quad \text{(case g)}
\end{aligned} \tag{25}
$$

For the situation described by (24), and with regards to (14), (18), (22) and (23), we can write the following system of equations for **case b**:

$$
\begin{aligned}
&(i=1) \\
&\qquad\vdots \qquad\qquad \vdots \qquad\qquad \vdots \\
&a_{i1}x_1 + a_{i2}x_2 + \ldots + \left(a_{ir} + a_{is} f_{s/r}^a + a_{it} f_{t/s}^a f_{s/r}^a\right)x_r + \ldots + a_{im}x_m + \\
&+\left[a_{i,m+1} + a_{iu} f_u^b + \left(a_{iv} + a_{iw} f_{w/v}^a + a_{ix} f_{x/v}^a + a_{iy} f_{y/x}^a f_{x/v}^a\right) f_v^b + a_{iz} \frac{f_z^c}{W^b}\right] \cdot X \approx u_i \\
&\qquad\vdots \qquad\qquad \vdots \qquad\qquad \vdots \\
&(i=n+1)
\end{aligned} \tag{26}
$$

and a little different system for **case g**:

$$
\begin{aligned}
&(i=1) \\
&\qquad\vdots \qquad\qquad \vdots \qquad\qquad \vdots \\
&a_{i1}x_1 + a_{i2}x_2 + \ldots + \left(a_{ir} + a_{is} f_{s/r}^a + a_{it} f_{t/s}^a f_{s/r}^a\right)x_r + \ldots + a_{im}x_m + \\
&+\left[a_{i,m+1} + a_{iu} f_u^b + \left(a_{iv} + a_{iw} f_{w/v}^a + a_{ix} f_{x/v}^a + a_{iy} f_{y/x}^a f_{x/v}^a\right) f_v^b\right] \cdot X \approx u_i - a_{iz} \frac{f_z^c \cdot U}{100 \cdot W^g} \\
&\qquad\vdots \qquad\qquad \vdots \qquad\qquad \vdots \\
&(i=n+1)
\end{aligned} \tag{27}
$$

It should be noted here that variables x_s through x_z are eliminated from systems of equations (26) and (27). This means that for every fixed raw material, the number of variables in the enlarged system of equations (17) is reduced by one. The number of x_j variables left in the system (q) is:

$$q = m - p \tag{28}$$

where p is the number of fixed raw materials. The total number of variables in the system is q+1, because the variable X is added.

Note that if there are no fixed raw materials, the total number of raw materials in the batch calculation m is limited by the number of oxides in the glass n ($m \le n$). In case there are fixed raw materials, the condition is transformed into ($q \le n$). This means that the maximum number of raw materials in the batch calculation is increased by the number of fixed raw materials.

We will define p^a, as number of raw materials fixed relative to other raw materials, p^b as number of raw materials fixed relative to total batch and p^c as number of raw materials fixed absolutely, it follows that:

(29) $$p = p^a + p^b + p^c$$

To make the systems of equations (26) and (27) more general and more readable, we will introduce new substitute coefficients a^c_{ij} (i=1...n+1; j=1...q+1) and u^c_i (i=1...n+1):

(30) $$a^c_{ij} = a_{ij} \qquad \left(i = 1...n+1;\ j = 1...m \text{ only not fixed } x_j \text{ NOT base for fixed } x_k\right)$$

(31) $$a^c_{ij} = a_{ij} + \sum_{s=1}^{p^a} a_{is}\, f^a_{s/j} \qquad \left(i = 1...n+1;\ j = 1...m \text{ only not fixed } x_j \text{ base for fixed } x_k\right)$$

Case b:

(32) $$a^c_{i,m+1} = a_{i,m+1} + \sum_{t=1}^{p^b} a_{it}\, f^b_t + \sum_{u=1}^{p^c} a_{iu} \frac{f^c_u}{W^b} \qquad (i = 1...n+1)$$

(33) $$u^c_i = u_i \qquad (i = 1...n+1)$$

Case g:

(34) $$a^c_{i,m+1} = a_{i,m+1} + \sum_{t=1}^{p^b} a_{it}\, f^b_t \qquad (i = 1...n+1)$$

(35) $$u^c_i = u_i - \sum_{u=1}^{p^c} a_{iu} \frac{f^c_u \cdot U}{100 \cdot W^g} \qquad (i = 1...n+1)$$

In case of nested fixes, we will calculate a^c_{ij} and u^c_i in a step by step fashion, starting from the lowest fix level (x_j that is not a base for any other fix).

By substituting (30) through (35) into the systems of equations (26) and (27), they become again unified as:

$$
\begin{aligned}
&a^c_{11}x_1 + a^c_{12}x_2 + ... + a^c_{1j}x_j + ... + a^c_{1q}x_q + a^c_{1,q+1}X \approx u^c_1 \\
&a^c_{21}x_1 + a^c_{22}x_2 + ... + a^c_{2j}x_j + ... + a^c_{2q}x_q + a^c_{2,q+1}X \approx u^c_2 \\
&\quad\vdots \qquad\quad \vdots \qquad\quad \vdots \\
&a^c_{i1}x_1 + a^c_{i2}x_2 + ... + a^c_{ij}x_j + ... + a^c_{iq}x_q + a^c_{i,q+1}X \approx u^c_i \\
&\quad\vdots \qquad\quad \vdots \qquad\quad \vdots \\
&a^c_{n1}x_1 + a^c_{n2}x_2 + ... + a^c_{nj}x_j + ... + a^c_{nq}x_q + a^c_{n,q+1}X \approx u^c_n \\
&a^c_{n+1,1}x_1 + a^c_{n+1,2}x_2 + ... + a^c_{n+1,j}x_j + ... + a^c_{n+1,q}x_q + a^c_{n+1,q+1}X = u^c_{n+1}
\end{aligned}
\tag{36}
$$

The number of variables in system (36) is q+1 because all p fixed variables are eliminated and X is added. The system of equations (36) can be solved in by applying a variation of the least squares method.

Least Squares Solution

For the purpose of finding the least squares solution of the system of equations (36), we will first define weighted errors (e_i) in the first n equations (i=1...n) of the system (36) with h_i as error weight coefficients:

$$e_i = h_i\left(a^c_{i1}x_1 + a^c_{i2}x_2 + ... + a^c_{ij}x_j + ... + a^c_{iq}x_q + a^c_{i,q+1}X - u^c_i\right) \quad (i = 1...n) \tag{37}$$

We will substitute the coefficients in (37) with new ones – a^d_{ij} and u^d_i:

$$a^d_{ij} = h_i a^c_{ij} \quad \left(i = 1...n;\ j = 1...q+1\right) \tag{37a}$$

$$u^d_i = h_i u^c_i \quad (i = 1...n) \tag{37b}$$

Next, we will define E^s as the sum of squares of weighted errors in the first n equations (i=1...n) of the system (36):

$$E^s = \sum_{i=1}^{n} e_i^2 = \sum_{i=1}^{n} (a^d_{i1}x_1 + a^d_{i2}x_2 + ... + a^d_{ij}x_j + ... + a^d_{iq}x_q + a^d_{i,q+1}X - u^d_i)^2 \tag{38}$$

To find values of x_j that produce the minimum E^s, we will equate partial derivatives of E^s by x_j with zero:

$$\frac{\partial E^s}{\partial x_j} = 0 \quad \left(j = 1...q\right) \tag{39}$$

From (38) and (39) we can write:

$$
\begin{aligned}
&\sum_{i=1}^{n} 2a_{i1}^{d}(a_{i1}^{d}x_1 + a_{i2}^{d}x_2 + ... + a_{ij}^{d}x_j + ... + a_{iq}^{d}x_q + a_{i,q+1}^{d}X - u_i^{d}) = 0 \\
&\sum_{i=1}^{n} 2a_{i2}^{d}(a_{i1}^{d}x_1 + a_{i2}^{d}x_2 + ... + a_{ij}^{d}x_j + ... + a_{iq}^{d}x_q + a_{i,q+1}^{d}X - u_i^{d}) = 0 \\
&\qquad\vdots \qquad\qquad\qquad\vdots \qquad\qquad\qquad\vdots \\
&\sum_{i=1}^{n} 2a_{ik}^{d}(a_{i1}^{d}x_1 + a_{i2}^{d}x_2 + ... + a_{ij}^{d}x_j + ... + a_{iq}^{d}x_q + a_{i,q+1}^{d}X - u_i^{d}) = 0 \\
&\qquad\vdots \qquad\qquad\qquad\vdots \qquad\qquad\qquad\vdots \\
&\sum_{i=1}^{n} 2a_{iq}^{d}(a_{i1}^{d}x_1 + a_{i2}^{d}x_2 + ... + a_{ij}^{d}x_j + ... + a_{iq}^{d}x_q + a_{i,q+1}^{d}X - u_i^{d}) = 0
\end{aligned}
\tag{40}
$$

By transforming the system of linear equations (40) and adding to it the last equation from (36), we obtain:

$$
\begin{aligned}
&x_1\sum_{i=1}^{n} a_{i1}^{d}a_{i1}^{d} + x_2\sum_{i=1}^{n} a_{i1}^{d}a_{i2}^{d} + ... + x_j\sum_{i=1}^{n} a_{i1}^{d}a_{ij}^{d} + ... + x_q\sum_{i=1}^{n} a_{i1}^{d}a_{iq}^{d} + X\sum_{i=1}^{n} a_{i1}^{d}a_{i,q+1}^{d} = \sum_{i=1}^{n} a_{i1}^{d}u_i^{d} \\
&x_1\sum_{i=1}^{n} a_{i2}^{d}a_{i1}^{d} + x_2\sum_{i=1}^{n} a_{i2}^{d}a_{i2}^{d} + ... + x_j\sum_{i=1}^{n} a_{i2}^{d}a_{ij}^{d} + ... + x_q\sum_{i=1}^{n} a_{i2}^{d}a_{iq}^{d} + X\sum_{i=1}^{n} a_{i2}^{d}a_{i,q+1}^{d} = \sum_{i=1}^{n} a_{i2}^{d}u_i^{d} \\
&\qquad\vdots \qquad\qquad\vdots \qquad\qquad\vdots \qquad\qquad\vdots \\
&x_1\sum_{i=1}^{n} a_{ik}^{d}a_{i1}^{d} + x_2\sum_{i=1}^{n} a_{ik}^{d}a_{i2}^{d} + ... + x_j\sum_{i=1}^{n} a_{ik}^{d}a_{ij}^{d} + ... + x_q\sum_{i=1}^{n} a_{ik}^{d}a_{iq}^{d} + X\sum_{i=1}^{n} a_{ik}^{d}a_{i,q+1}^{d} = \sum_{i=1}^{n} a_{ik}^{d}u_i^{d} \\
&\qquad\vdots \qquad\qquad\vdots \qquad\qquad\vdots \qquad\qquad\vdots \\
&x_1\sum_{i=1}^{n} a_{iq}^{d}a_{i1}^{d} + x_2\sum_{i=1}^{n} a_{iq}^{d}a_{i2}^{d} + ... + x_j\sum_{i=1}^{n} a_{iq}^{d}a_{ij}^{d} + ... + x_q\sum_{i=1}^{n} a_{iq}^{d}a_{iq}^{d} + X\sum_{i=1}^{n} a_{iq}^{d}a_{i,q+1}^{d} = \sum_{i=1}^{n} a_{iq}^{d}u_i^{d} \\
&x_1 \cdot a_{n+1,1}^{c} + x_2 \cdot a_{n+1,2}^{c} + ... + x_j \cdot a_{n+1,j}^{c} + ... + x_q \cdot a_{n+1,q}^{c} + X \cdot a_{n+1,q+1}^{c} = u_{n+1}^{c}
\end{aligned}
\tag{41}
$$

The quantities of each raw material (x_j; j = 1..q) can be obtained by solving the above system of equations (41). By substituting new coefficients b_{kj} (k=1...q+1; j=1...q+1;) and c_k (k=1...q+1) given as:

$$b_{kj} = \sum_{i=1}^{n} a_{ik}^{d}a_{ij}^{d} \qquad \left(k = 1...q;\ \ j = 1...q+1\right) \tag{42}$$

$$b_{q+1,j} = a_{n+1,j}^{c} \qquad \left(j = 1...q+1\right) \tag{43}$$

$$c_k = \sum_{i=1}^{n} a_{ik}^{d}u_i^{d} \qquad \left(k = 1...q\right) \tag{44}$$

$$c_{q+1} = u_{n+1}^{c} \tag{45}$$

into the system of equations (41), we obtain:

$$
\begin{aligned}
& b_{11}x_1 + b_{12}x_2 + ... + b_{1j}x_j + ... + b_{1q}x_q + b_{1,q+1}X = c_1 \\
& b_{21}x_1 + b_{22}x_2 + ... + b_{2j}x_j + ... + b_{2q}x_q + b_{2,q+1}X = c_2 \\
& \quad : \qquad\qquad : \qquad\qquad : \\
& b_{k1}x_1 + b_{k2}x_2 + ... + b_{kj}x_j + ... + b_{kq}x_q + b_{k,q+1}X = c_k \\
& \quad : \qquad\qquad : \qquad\qquad : \\
& b_{q1}x_1 + b_{q2}x_2 + ... + b_{qj}x_j + ... + b_{qq}x_q + b_{q,q+1}X = c_q \\
& b_{q+1,1}x_1 + b_{q+1,2}x_2 + ... + b_{q+1,j}x_j + ... + b_{q+1,q}x_q + b_{q+1,q+1}X = c_{q+1}
\end{aligned} \tag{42}
$$

or in matrix form:

$$\mathbf{B} \cdot \mathbf{X} = \mathbf{C} \tag{43}$$

where:

$$
\mathbf{B} = \begin{bmatrix}
b_{11} & b_{12} & ... & b_{1j} & ... & b_{1q} & b_{1,q+1} \\
b_{21} & b_{22} & ... & b_{2j} & ... & b_{2q} & b_{2,q+1} \\
: & : & : & : & : & : & : \\
b_{k1} & b_{k2} & ... & b_{kj} & ... & b_{kq} & b_{k,q+1} \\
: & : & : & : & : & : & : \\
b_{q1} & b_{q2} & ... & b_{qj} & ... & b_{qq} & b_{q,q+1} \\
b_{q+1,1} & b_{q+1,2} & ... & b_{q+1,j} & ... & b_{q+1,q} & b_{q+1,q+1}
\end{bmatrix} \tag{44}
$$

$$
\mathbf{X} = \begin{bmatrix}
x_1 \\ x_2 \\ : \\ x_j \\ : \\ x_q \\ X
\end{bmatrix} \tag{45}
$$

$$
\mathbf{C} = \begin{bmatrix}
c_1 \\ c_2 \\ : \\ c_k \\ : \\ c_q \\ c_{q+1}
\end{bmatrix} \tag{46}
$$

By solving the system of equation (42) or (43) we will obtain the quantities of raw materials in batch (x_j ; j = 1..q). To do that, we shall first invert the square matrix **B** [b_{kj} (k=1..q+1, j=1..q+1)] into matrix $\mathbf{B}^{-1}$ [b^i_{kj} (k=1..q+1, j=1..q+1)]:

(47) $$\mathbf{B}^{-1} = \begin{bmatrix} b^i_{11} & b^i_{12} & \dots & b^i_{1j} & \dots & b^i_{1q} & b^i_{1,q+1} \\ b^i_{21} & b^i_{22} & \dots & b^i_{2j} & \dots & b^i_{2q} & b^i_{2,q+1} \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ b^i_{k1} & b^i_{k2} & \dots & b^i_{kj} & \dots & b^i_{kq} & b^i_{k,q+1} \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ b^i_{q1} & b^i_{q2} & \dots & b^i_{qj} & \dots & b^i_{qq} & b^i_{q,q+1} \\ b^i_{q+1,1} & b^i_{q+1,2} & \dots & b^i_{q+1,j} & \dots & b^i_{q+1,q} & b^i_{q+1,q+1} \end{bmatrix}$$

Having found $\mathbf{B}^{-1}$, the vector **X** in (43) can be calculated as:

(48) $$\mathbf{X} = \mathbf{C} \cdot \mathbf{B}^{-1}$$

or in algebraic notation:

(49)
$$\begin{aligned} x_1 &= b^i_{11}c_1 + b^i_{12}c_2 + \dots + b^i_{1j}c_j + \dots + b^i_{1q}c_q + b^i_{1,q+1}c_{q+1} \\ x_2 &= b^i_{21}c_1 + b^i_{22}c_2 + \dots + b^i_{2j}c_j + \dots + b^i_{2q}c_q + b^i_{2,q+1}c_{q+1} \\ &\vdots \qquad\qquad \vdots \qquad\qquad \vdots \\ x_k &= b^i_{k1}c_1 + b^i_{k2}c_2 + \dots + b^i_{kj}c_j + \dots + b^i_{kq}c_q + b^i_{k,q+1}c_{q+1} \\ &\vdots \qquad\qquad \vdots \qquad\qquad \vdots \\ x_q &= b^i_{q1}c_1 + b^i_{q2}c_2 + \dots + b^i_{qj}c_j + \dots + b^i_{qq}c_q + b^i_{q,q+1}c_{q+1} \\ X &= b^i_{q+1,1}c_1 + b^i_{q+1,2}c_2 + \dots + b^i_{q+1,j}c_j + \dots + b^i_{q+1,q}c_q + b^i_{q+1,q+1}c_{q+1} \end{aligned}$$

Equations (48) and (49) represent the least squares solution of the system of equations (36). Note that X is the sum of all raw material quantities, as given by equation (3).

The technique used by TriBatch internal math engine for finding the least squares solution of the system of equations (36) is the QR decomposition (also called the QR factorization), by means of Householder reflections (or Householder transformation). A good explanation of this technique can be found at http://en.wikipedia.org/wiki/QR_decomposition.

Finalizing the Calculation

After calculating x_1 ... x_q and X, we can now determine the fixed raw material quantities. According to (20) and (21), the raw material quantities x_k fixed absolutely can in **case b** be calculated from:

(50) $$x_k = f_k^c \cdot \frac{X}{W^b} \quad \left(k = 1...p^c\right)$$

and in **case g** from:

(51) $$x_k = f_k^c \cdot \frac{U}{100 \cdot W^g} \quad \left(k = 1...p^c\right)$$

Next, we will calculate the values of x_k fixed relative to batch weight. According to (16), we can write:

(60) $$x_k = f_k^b \cdot X \quad \left(k = 1...p^b\right)$$

Finally, we will calculate all x_k fixed relative to other raw materials. According to (13):

(61) $$x_k = f_k^{a,r} \cdot x_r \quad \left(k = 1...p^a\right)$$

In case of nested relative fixes, we will apply step by step solution, starting from x_k that is fixed relative to already calculated raw material quantity.

After calculating all raw material quantities x_1... x_m, we will determine the calculated values of oxide percentages in glass v_i (i=1...n) from (7a). We can also obtain the total of calculated oxide percentages V from (7b).

At this point we should verify the V=U assumption we made in (8). If there is a discrepancy, all calculated raw material quantities x_j (j=1...m) and their total X should be adjusted by multiplying them with the ratio of U/V:

(62) $$x_j = x_j \frac{U}{V} \quad \left(j = 1...m\right)$$

(63) $$X = X \frac{U}{V}$$

After that, we should use (7a) and (7b) to calculate v_i *(*i=*1...*n*) and* V *again.*

Next, referring to equation (11), we can calculate batch and glass weights (W^b and W^g).

Case b:

(64) $$W^b = W^{bt}$$

(65) $$W^g = \frac{W^{bt} \cdot V}{100 \cdot X}$$

Case g:

(66) $$W^b = \frac{100 \cdot W^{gt} \cdot X}{V}$$

(67) $$W^g = W^{gt}$$

With W^b and W^g determined, we can calculate loss of ignition Y from (10). Finally, we can calculate raw material weights form (4), and if required, oxide weights (v^w_i) from the following equation based on (2):

(68) $$v_i^w = v_i \cdot \frac{W^g}{V} \qquad (i = 1...n)$$

We can also calculate raw material yield weights (y^w_j) from:

(69a) $$y_j^w = x_j^w \frac{y_j}{100} \qquad \left(j = 1...m\right)$$

raw material loss of ignition weights l^w_j from:

(69b) $$l_j^w = x_j^w - y_j^w \qquad \left(j = 1...m\right)$$

As another check, we should confirm that the following relationship, derived from (10), is satisfied:

(70) $$W^g = \sum_{i=1}^{n} v_i^w = \sum_{i=1}^{n} u_i^w = \sum_{j=1}^{m} \left(x_j^w \frac{y_j}{100} \right)$$

If specific prices (per unit weight) of individual raw materials (s_j) are given, we can calculate specific batch cost (S^b) and specific glass cost (S^g) from the following two equations:

(71) $$S^b = \frac{\sum_{i=1}^{n} s_j x_j^w}{W^b}$$

(72) $$S^g = \frac{\sum_{i=1}^{n} s_j x_j^w}{W^g} = S^b \frac{W^b}{W^g}$$

At the end, it may be interesting to calculate standard errors in actual oxide percentages (E^a) and weighted oxide percentages (E^h) from:

(73) $$E^a = \sqrt{\frac{\sum_{i=1}^{n} \left(v_i - u_i\right)^2}{n}}$$

(74) $$E^h = \sqrt{\frac{\sum_{i=1}^{n} h_i^2 \left(v_i - u_i\right)^2}{\sum_{i=1}^{n} h_i^2}}$$

Additional Conditions and Adjustments

In some cases, the results of batch calculation have to fulfill some additional conditions. Sections 5.1. through 5.5. describe these conditions and the means of satisfying them.

Oxide Groups

Oxide groups can be used when target glass composition specifies some of the oxides lumped together (as in CaO+MgO). When two or more oxides belong to a group, only the sum of their percentages is taken into account when calculating the target glass composition.

A group containing two or more oxides is treated in almost all respects as a single oxide. In order to make the batch sheet more readable, the oxides belonging to the same group must be contiguous. For example, oxides 4, 5 and 6 can be grouped together, while oxides 3, 6 and 8 cannot.

The initial system of equations with all oxides treated individually (no groups) can be written as:

$$
\begin{aligned}
& a^i_{11}x_1 + a^i_{12}x_2 + \ldots + a^i_{1j}x_j + \ldots + a^i_{1m}x_m = u^i_1 \\
& a^i_{21}x_1 + a^i_{22}x_2 + \ldots + a^i_{2j}x_j + \ldots + a^i_{2m}x_m = u^i_2 \\
& \quad\vdots \qquad\qquad \vdots \qquad\qquad \vdots \\
& a^i_{i1}x_1 + a^i_{i2}x_2 + \ldots + a^i_{ij}x_j + \ldots + a^i_{im}x_m = u^i_i \\
& \quad\vdots \qquad\qquad \vdots \qquad\qquad \vdots \\
& a^i_{n^i 1}x_1 + a^i_{n^i 2}x_2 + \ldots + a^i_{n^i j}x_j + \ldots + a^i_{n^i m}x_m = u^i_{n^i}
\end{aligned}
\tag{75}
$$

where a^i_{ij} (i=1...n^i; j=1...m) coefficients are percentages of all individual oxides i in raw material j, (adjusted for evaporation as described in 5.2), u^i_i (i=1...n^i) are target percentages of individual oxides in glass and n^i is the total number of individual oxides before any adjustments.

The number of oxide groups contained in the system (75) is g, and the numbers of oxides in each group is n^g_k (k=1...g). We can calculate the number of individual oxides plus number of oxide groups that will take part in the calculation (n) as:

$$
n = n^i - \sum_{k=1}^{g}\left(n^g_k - 1\right) \tag{76}
$$

Let us suppose that oxides s through $s+ n^g_k-1$ are assigned to group k, which is then assigned oxide number r. In this case, the coefficients a_{ij} and u_i in the system of equations (7) are calculated from the coefficients a^i_{ij} in (75) as:

$$
a_{rj} = \sum_{i=s}^{s+n^g_k-1} a^i_{ij} \qquad \left(j = 1...m;\ \text{only oxides within groups}\right) \tag{77}
$$

$$
a_{i-k,j} = a^i_{ij} \qquad \left(j = 1...m;\ \text{only individual oxides}\right) \tag{78}
$$

(79a) $u_r = \sum_{i=s}^{s+n_k^g-1} u_i^i \quad (\text{oxides within groups})$

(79b) $u_{i-k} = u_i^i \quad (\text{oxides not belonging to groups})$

Note that constants u_i in the system of equations (7) are the target percentage for the group of oxides, which is usually given as an input.

Once the system (7) is derived from the system (75), the calculation may proceed as described in sections 1 through 4. Upon completing he calculation, it is also possible to determine the calculated percentages of oxides within groups from the equations in (75).

Raw Material Carryover and Oxide Evaporation Losses

A small percentage of each raw material weight is usually lost due to its moisture content and carryover into the flue gas and it is exhausted from the furnace. Also, small percentage of some of the oxides can be lost due to evaporation from molten glass. This effectively reduces the oxide yield below the theoretical value.

We will account for this effect by introducing carryover coefficients for each raw material d_j^{rm} (j=1...*m)* and evaporation coefficients for each oxide d_i^{ox} (i=1...*n).* We will use them to modify the original input a^0_{ij} coefficients (percentage of oxide or group i in raw material j,) and obtain a^i_{ij} coefficients used in (75):

(80) $$a_{ij}^i = a_{ij}^0 \cdot \left(1 - \frac{d_j^{rm}}{100}\right) \cdot \left(1 - \frac{d_i^{ox}}{100}\right) \quad (i = 1...n^i; j = 1...m)$$

Oxide Saturation

Chemical and physical balance of glass melt may cause an oxide from to have a saturation percentage in glass. If the batch contains a quantity of such oxide that is larger than the quantity required to reach its saturation percentage in glass, the excess amount is released into the flue gas. For example, the saturation percentage of SO_3 is is usually 0.3 to 0.5%.

We will account for this effect by introducing u^m_i (i=1...n^1) constants representing maximum percentages of oxides in glass, where n^1 is number of oxides + groups (including those over the saturation limits). All calculated oxide (and group) percentages have to fulfill the following relation:

(81) $$v_i \le u_i^m \quad (i = 1..n^1)$$

The target percentges u_i have to meet the same condition, otherwise an error in input data is reported:

(82) $$u_i \le u_i^m \quad (i = 1...n^1)$$

Note that for an oxide group there is only one summary maximum percentage (u^m_i) and that the percentage of individual oxides within a group cannot be limited.

If upon batch calculation some of v_i do not satisfy relation (81), then such oxides (their number is n^x) are removed from the system of equations (7), the target percentages of the

remaining oxides and groups are adjusted, and the calculation is repeated. When reducing the number of oxides (*n*), attention has to be paid not to go below the number of variables left in the system after removing fixed raw materials (*q*).

(83) $$n = n^1 - n^x \quad \left(n \geq q\right)$$

If there is a need to adjust the calculation for the over the saturation limit oxides, the system of equations (7) (with all the oxides and groups present) is first duplicated into:

(84)
$$\begin{aligned}
&a^1_{11}x_1 + a^1_{12}x_2 + ... + a^1_{1j}x_j + ... + a^1_{1m}x_m = u^1_1 \\
&a^1_{21}x_1 + a^1_{22}x_2 + ... + a^1_{2j}x_j + ... + a^1_{2m}x_m = u^1_2 \\
&\quad\vdots \qquad\qquad\quad \vdots \qquad\qquad\quad \vdots \\
&a^1_{i1}x_1 + a^1_{i2}x_2 + ... + a^1_{ij}x_j + ... + a^1_{im}x_m = u^1_i \\
&\quad\vdots \qquad\qquad\quad \vdots \qquad\qquad\quad \vdots \\
&a^1_{n^1 1}x_1 + a^1_{n^1 2}x_2 + ... + a^1_{n^1 j}x_j + ... + a^1_{n^1 m}x_m = u^1_{n^1}
\end{aligned}$$

When the calculation is completed, all the oxides exceeding the percentage limits should be exactly at those limits, regardless of their target percentages. In order to solve the equations by minimizing the percentage errors of the remaining oxides, their target compositions will be reduced in such a way that they do not have to be normalized at the end. For that purpose, we will first calculate the sum of u^1_i as:

(85) $$U^1 = \sum_{i=1}^{n^1} u^1_i$$

Next, we will calculate U^x as the sum of all target percentages for over the saturation limit oxides:

(86) $$U^x = \sum_{i=1}^{n^x} u^1_i$$

and U^m as the sum of all maximum percentages for over the saturation limit oxides:

(87) $$U^m = \sum_{i=1}^{n^x} u^m_i$$

If $U^m > U^x$, then we will adjust u_i for the remaining oxides before repeating the calculation:

(88) $$u_i = u^1_{i-k} \cdot \frac{U^1 - U^m}{U^1 - U^x} \quad (i = 1...n)$$

After taking out the oxides with percentages over the saturation limits and adjusting the target percentages of the remaining ones, the system (84) is reduced back to system (7), and the calculation is repeated as described in sections 1. through 4.

Upon the second round of calculation, the calculated oxide and group percentages are determined. Based on (81) and (84), we can write:

(89) $$v_i^1 = \min\left\{\sum_{j=1}^{m} a_{ij}^1 x_j;\ u_i^m\right\} \quad \left(i = 1...n^1\right)$$

and:

(90) $$V^1 = \sum_{i=1}^{n^1} v_i^1$$

After that, we will perform a check of whether the final sum of calculated oxide percentages equals the sum of target percentages:

(91) $$V^1 \equiv U^1$$

Condition (91) will not be met if the set of oxides over the saturation limits is not the same as the one after the previous round of calculation. In that case, the procedure should be repeated. Once condition (91) is met, we will have to re-calculate the final results.

In **case b** we will use equations (64) and (65), followed by (4) and (68) through (74).

Case g is more complicated. By solving the system (7) without over the saturation limit oxides present, the calculated glass weight W^g will be, according to (67) and (70):

(92) $$W^g = \sum_{i=1}^{n} v_i^w = W^{gt}$$

However, the **case g** boundary condition states that the actual weight of glass, meaning the calculated glass weight after all adjustments (W^{g1}), should be equal to the target glass weight W^{gt}. We can calculate W^{g1} from:

(93) $$W^{g1} = \sum_{i=1}^{n^1} v_i^{w1}$$

where, with reference to (68):

(94) $$v_i^{w1} = v_i^1 \cdot \frac{W^g}{U} \quad \left(i = 1...n^1\right)$$

By comparing W^g and W^{gt} from (92) with W^{g1} from (94), it is obvious that in **case g** with over the saturation limit oxides, the final calculated glass weight (W^{g1}) is greater than the target glass weight (W^{gt}). Therefore, an adjustment of some kind is required. We will adjust all calculated weights by multiplying them by W^{gt}/W^{g1} ratio:

(95) $$x_j^{w2} = x_j^w \cdot \frac{W^{gt}}{W^{g1}} \quad \left(j = 1...m\right)$$

(96) $$v_i^{w2} = v_i^{w1} \cdot \frac{W^{gt}}{W^{g1}} \quad \left(i = 1...n^1\right)$$

(97) $$W^{b2} = W^b \cdot \frac{W^{gt}}{W^{g1}}$$

(98) $$W^{g2} = W^{g1} \cdot \frac{W^{gt}}{W^{g1}} = W^{gt}$$

However, if one or more raw materials are fixed absolutely, (p^c>0), applying equation (95) would also change (reduce) their weights. In order to find a solution that will satisfy all the fixes, we will apply an iterative method. We will first increase all raw material absolute fix values in the following manner:

(99) $$f_j^c = f_j^{c0} \cdot \frac{W^{g1}}{W^{gt}} \quad \left(j = 1...p^c\right)$$

where f_j^{c0} are the original absolute fix values. This process is repeated until the errors in calculated quantities of all fixes raw materials fall below the maximum error $E^{x,\max}$:

(100) $$\left|\left(x_j^{w2} - f_j^{c0}\right)\frac{X}{W^b}\right| < E^{x,\max} \quad \left(j = 1...p^c\right)$$

Percentage of Oxide in Glass Tolerances

Note: The percentage of oxide in glass tolerances constraint is currently not implemented in the TriBatch internal math model. It can, however, be imposed by using Solver.

In some cases, it may not be desirable to calculate the batch with the lowest total sum of errors squared, but it may be paramount to keep percentages of certain oxides in specified tolerances, while letting the others float more freely. For that purpose, we will define t_i (i=1...n^1) as oxide or group percentage tolerances.

Upon completing the calculation, including over the saturation limit adjustments, we will first check if all calculated oxide percentages $v^1{}_i$ fall within the specified tolerances:

(101) $$\left|v_i^1 - u_i^0\right| < d_i \quad \left(i = 1...n^1\right)$$

For those oxides that don't satisfy condition (101), we will adjust target percentages $u^1{}_i$ as follows:

(102) $$u_i^1 = u_i^{1p} + \left[\left(u_i^0 - d_i\right) - v_i^{1p}\right] = u_i^{1p} + u_i^0 - v_i^{1p} - d_i \qquad \left(\text{for: } v_i^{1p} < u_i^0 - d_i\right)$$

(103) $$u_i^1 = u_i^{1p} - \left[v_i^{1p} - \left(u_i^0 + d_i\right)\right] = u_i^{1p} + u_i^0 - v_i^{1p} + d_i \qquad \left(\text{for: } v_i^{1p} > u_i^0 + d_i\right)$$

Obviously, adjusting the oxide target percentages for out of tolerance oxides will change the total percentage of all oxides in glass U^1. To compensate, we will also adjust the target percentages of the free oxides. For that reason, we will first calculate the total of target percentages of out of tolerance oxides (U^{1x}) after adjustments (102) and (103):

(104) $$U^{1x} = \sum_{i=1}^{n^t} u_i^1 \quad \left(\text{out of tolerance oxides}\right)$$

and the total before any tolerance adjustments:

(105) $$U^{0x} = \sum_{i=1}^{n^t} u_i^0 \quad \left(\text{out of tolerance oxides}\right)$$

where n^t is the number of out of tolerance oxides. We will then adjust u^0_i for the remaining oxides before repeating the calculation:

(106) $$u_i^1 = u_{i-k}^0 \cdot \frac{U^0 - U^{1x}}{U^0 - U^{0x}} \qquad (i = \text{free oxides})$$

With all new u^1_i determined, the calculation process is repeated, and the tolerances checked again.