

51. Mass Balance Module



TOC:

51.1.	Where do we need mass balancing?	2
51.2.	Mass balancing capabilities in HSC Chemistry® 8	3
51.3.	Overview of the HSC Sim 8 Mass Balancing tool	5
51.4.	Step-by-step example: data reconciliation and mass balancing in HSC 8.....	6
51.4.1.	Drawing the flowsheet	6
51.4.2.	Importing the experimental data	6
51.4.3.	Reviewing and complementing the data	9
51.4.4.	Setting the measurement accuracies	11
51.4.5.	Mass balancing	13
51.4.6.	Reporting and reviewing the results	15
51.4.7.	Importing HSC7 Excel files	16
51.5.	Mass balance buttons and dropdowns	19
51.6.	Error check messages	22
51.7.	Mathematics and algorithms	23
51.7.1.	Unsize (bulk) mass balance.....	23
51.7.2.	Sized mass balance (without sized analyses)	25
51.7.3.	Sized by assay mass balance	26
51.8.	References.....	29

51.1. Where do we need mass balancing?

Mass balancing is a common practice in metallurgy. The mass balance of a circuit is needed for several reasons:

1. To estimate the metallurgical performance of the circuit
2. To locate process bottlenecks and for circuit diagnosis
3. To create models of the processing stages
4. To simulate the process.

The following steps are often required to simulate a process:

1. Collecting experimental data (experimental work, sampling, sample preparation, assaying)
2. Mass balancing and data reconciliation of the experimental data
3. Model building
4. Simulation.

In HSC Chemistry® 8, you can do all the steps in one program: *HSC Sim* with the *Mass Balance* tool. The work flow in the HSC Sim and Mass Balance tool starts from a flowsheet drawing, followed by importing experimental data, performing mass balancing, model fitting & building (model fitting will be available later on) and simulation (**Fig. 1**).

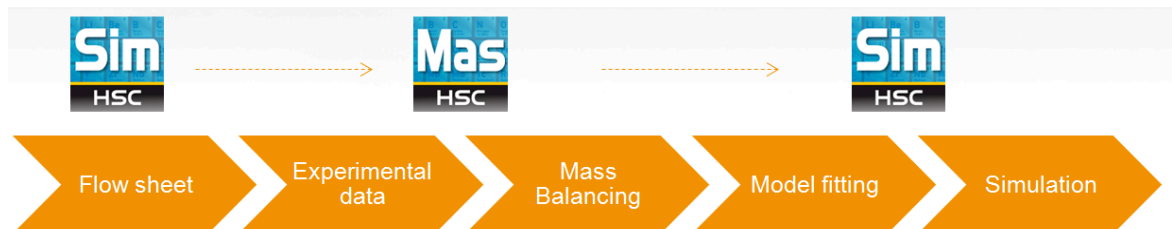


Fig. 1. From flowsheet with data through mass balancing to modeling and simulation.

51.2. Mass balancing capabilities in HSC Chemistry® 8

HSC 8 allows the user to solve the following mass balance problems (**Table 1**). There are three different possibilities for the solution:

- Solids
- Assays only
- Solids and water independently

Liquid flow rates and %solids are solved only if Solve solids and water independently is chosen. If Assays only is chosen, there must be a Total solids measurements for all the flows to be balanced.

1. Unsized
 - Balance Total Solids flow rates. At least one total solids flow rate measurement must be given
 - Balance Total Water/liquid flow rate. This is done by first balancing the Total solids flow rates and after that the Total Water/liquid flow rate independently
 - Balance %solids
 - Balance Solids component assays/Mineral assay. At least one solids component assay or mineral assay must exist
2. Sized
 - Balance Total Solids flow rates for bulk and all the size fractions. At least one total solids flow rate measurement for bulk must be given
 - Balance size fraction wt-% for size fractions
 - Balance Total Water/liquid flow rate for bulk. This is done by first balancing the Total solids flow rates and after that Total Water/liquid flow rate independently
 - Balance %solids for bulk
 - Balance Solids component assays/Mineral assay for bulk. If no solids component assays/mineral assays exist, the solids component assays/mineral assays for bulk are not balanced
3. Sized by assay
 - Balance Total Solids/Slurry flow rates for bulk and all the size fractions. At least one total solids/slurry flow rate measurement must be given
 - Balance size fraction wt-% for size fractions
 - Balance Total Water/liquid flow rate for bulk. This is done by first balancing the Total solids flow rates and after that Total Water/liquid flow rate independently
 - Balance %solids for bulk
 - Balance Solids component assays/Mineral assay for bulk and the size fractions

Table 1. Mass balance cases that can be solved with HSC Sim.

Measured or estimated values	Unsize Components	Sized	Sized by Assays
<i>Total solids flow rates</i>	X	X	X
<i>Water/Liquid flow rates</i>	X	X	X
<i>Solids component Assay/Mineral Assay bulk</i>	X	X	X
<i>Solid Component Assays/Mineral assays Size Fractions</i>	X		X
<i>%Solids</i>	X	X	X
<i>Fraction m%</i>		X	X
<i>Total Solids Flow rate size fractions</i>		X	X

51.3. Overview of the HSC Sim 8 Mass Balancing tool

The HSC Mass Balance tool is started from the HSC 8 Main Menu dialog or from HSC Sim Menu: Tools → Mass Balance. The window layout consists of: Balancing Navigator, Working Area, Property Panel, and Upper Buttons.

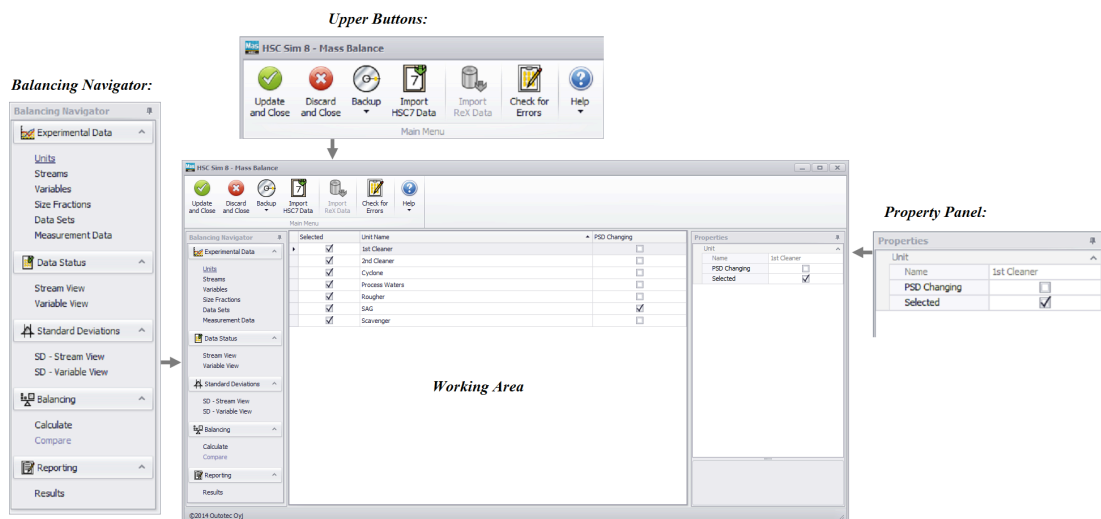


Fig. 2. Main components of the Mass Balance window.

51.4. Step-by-step example: data reconciliation and mass balancing in HSC 8

This step-by-step example shows how to do mass balancing for unsized data, consisting of the solids flow rates and assayed element (Cu, Ni, S) for a rougher-scavenger flotation bank. The work starts from HSC Sim 8 by drawing the process flowsheet. The Mass Balance tool is started from the HSC Sim Tools menu. The steps to import the data and to balance it follow the left side Balancing Navigator panel (**Fig. 2**) from top to bottom. More examples are found in Chapter 52.

51.4.1. Drawing the flowsheet

First the flowsheet is prepared in HSC Sim 8. In this rougher-scavenger flotation example it looks as shown in **Fig. 3**.

You can draw all the streams and units. HSC will create the mass balance equations according to the available data; therefore, there is no need to draw a flowsheet for mass balancing only or a new flowsheet every time for different kinds of mass balance problems.

When naming the streams, use identical names to those in your analysis lists. Before proceeding, please check the stream connections and check the flowsheet for possible errors.

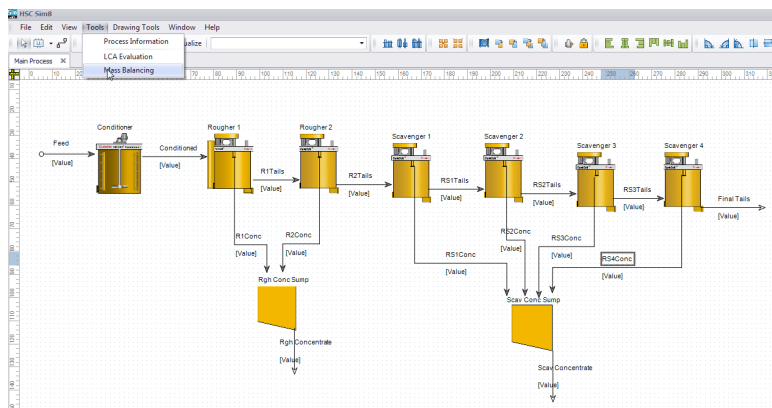


Fig. 3. HSC Sim flowsheet drawing of a flotation process with rougher and scavenger cells.

51.4.2. Importing the experimental data

When the flowsheet is ready (i.e. all streams are named properly and connections have been checked), you can import your experimental data. The following subsections will concentrate on how to import the data for mass balancing and data reconciliation.

1. Select units

The units are listed based on the flowsheet drawing figure, but they cannot be edited here. In this view you can:

- Select or deselect the units to be included in the balancing calculation.
- Set whether the unit will change the particle size distribution of the solids, e.g. grinding mills. This selection is needed in sized balancing, to indicate that the fraction balance will not be held over those units.

Import Data

Import ReX Data

Check for Errors

Help

Main Menu

Selected	Unit Name	PSD Changing
<input checked="" type="checkbox"/>	1st Cleaner	<input type="checkbox"/>
<input checked="" type="checkbox"/>	2nd Cleaner	<input type="checkbox"/>
<input checked="" type="checkbox"/>	Cyclone	<input type="checkbox"/>
<input checked="" type="checkbox"/>	Process Waters	<input type="checkbox"/>
<input checked="" type="checkbox"/>	Rougher	<input type="checkbox"/>
<input checked="" type="checkbox"/>	SAG	<input checked="" type="checkbox"/>
<input checked="" type="checkbox"/>	Scavenger	<input type="checkbox"/>

Fig. 4. Experimental Data – Units.

2. Select streams

The streams are listed based on the flowsheet drawing figure, but they cannot be edited here.

Here you can:

- Select and deselect the streams to be included in the balancing calculation.
- Change the stream type:
 - Unknown
 - Solids/Slurry
 - Liquid/Water

By default it is unknown, since the data has not yet been imported. When importing the data, the type is detected by pressing Detect stream types, but it can be changed here.

Selected	Type	Stream Name	Source	Destination
<input checked="" type="checkbox"/>	Unknown	Conditioned	Conditioner	Rougher 1
<input checked="" type="checkbox"/>	Unknown	Feed	?	Conditioner
<input checked="" type="checkbox"/>	Unknown	Final Tails	Scavenger 4	?
<input checked="" type="checkbox"/>	Unknown	R1Conc	Rougher 1	Rgh Conc Sump
<input checked="" type="checkbox"/>	Unknown	R1Tails	Rougher 1	Rougher 2
<input checked="" type="checkbox"/>	Unknown	R2Conc	Rougher 2	Rgh Conc Sump
<input checked="" type="checkbox"/>	Unknown	R2Tails	Rougher 2	Scavenger 1
<input checked="" type="checkbox"/>	Unknown	Rgh Concentrate	Rgh Conc Sump	?
<input checked="" type="checkbox"/>	Unknown	RS1Conc	Scavenger 1	Scav Conc Sump
<input checked="" type="checkbox"/>	Unknown	RS1Tails	Scavenger 1	Scavenger 2
<input checked="" type="checkbox"/>	Unknown	RS2Conc	Scavenger 2	Scav Conc Sump
<input checked="" type="checkbox"/>	Unknown	RS2Tails	Scavenger 2	Scavenger 3
<input checked="" type="checkbox"/>	Unknown	RS3Conc	Scavenger 3	Scav Conc Sump
<input checked="" type="checkbox"/>	Unknown	RS3Tails	Scavenger 3	Scavenger 4
<input checked="" type="checkbox"/>	Unknown	RS4Conc	Scavenger 4	Scav Conc Sump
<input checked="" type="checkbox"/>	Unknown	Scav Concentrate	Scav Conc Sump	?

Fig. 5. Experimental Data – Streams.

3. Add variables

Next, the measured variables are added / removed from the upper bar buttons. The variable name and unit on the list can be edited, and the variable can also be unselected from balancing if desired. The variable types are listed in **Table 2**.

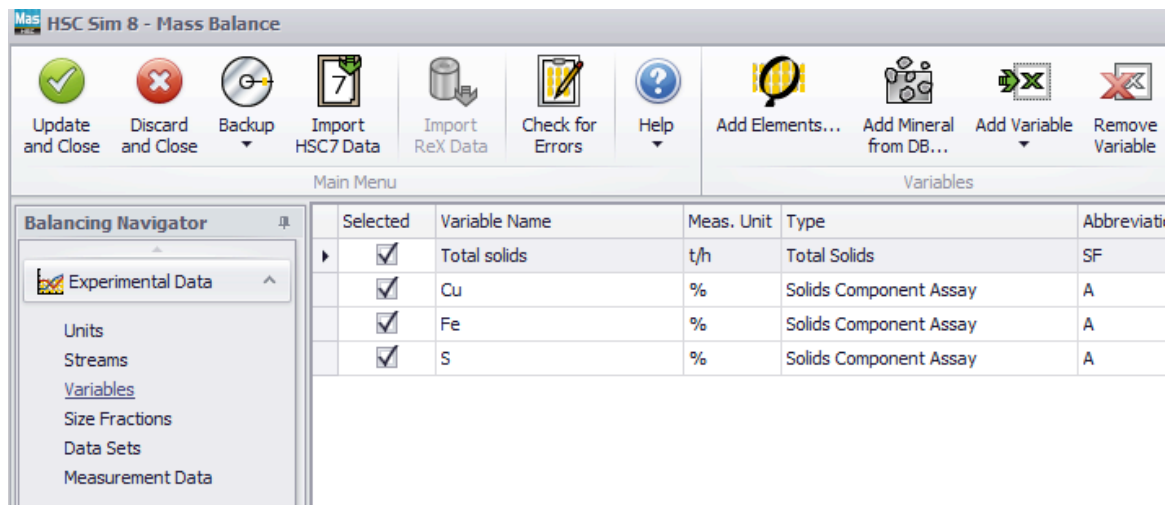


Fig. 6. Experimental Data – Variables.

Table 2. Data types of the variables.

Data type	Abbreviation	Examples
Total solids flow rate	SF	Total t/h, g
Solids component flow rate	SC	Iron t/h, plastic t/h, g
Solids component assay	A	Cu%, P2O5%
Mineral assay	M	Ccp%, Py%, Qtz%
Size Fraction wt %	SA	0-20um %, 20-45um %
Solids percentage	SP	35%
Not included	NA	Column with comments, extra data (temperature), etc.

4. Add size fractions

By default, one size fraction exists: 'Bulk', which cannot be removed. More size fractions can be added to /removed from the list by clicking the buttons on the upper bar. Fraction names can be given.

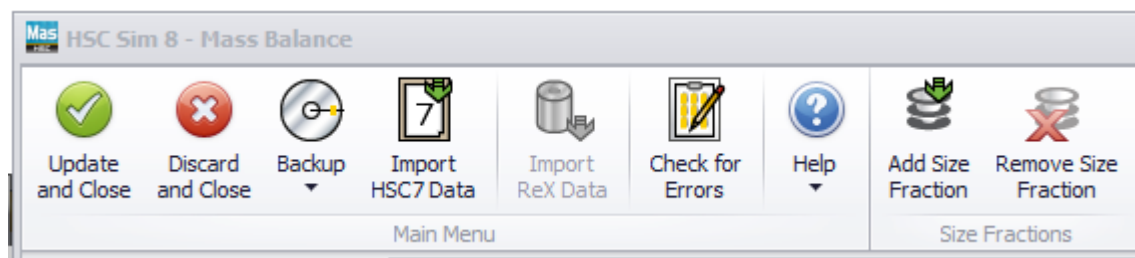


Fig. 7. Experimental Data – Size Fractions.

5. Add dataset(s)

By default, one dataset exists, which can be renamed here. In addition, more datasets can be added and selected one at a time to carry out data reconciliation.

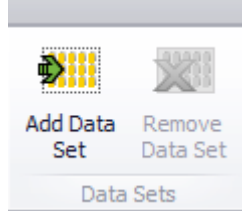


Fig. 8. Experimental Data – Datasets.

6. Import measurement data

In this view, a stream variable template is automatically generated and displayed. The data can be entered by:

- Typing manually in the table
- Copying an empty data template → organizing the data e.g. in Excel → select 'Paste Experimental Data'. This will automatically place the data in the correct rows and columns based on the clipboard table content.
- Importing the old HSC7 Analyses.xls mass balance file

Each dataset is presented in a separate table tab.

Stream	Fraction	Fraction m%	Total Solids t/h	Cu %	Fe %	S %
1 ROM	Bulk		112.000	1.004	6.096	7.000
2 ROM	0-20 um	1.000		1.004	6.096	7.000
3 ROM	20-37 um	2.000		1.004	6.096	7.000
4 ROM	37-74 um	5.000		1.004	6.096	7.000
5 ROM	74-106 um	12.000		1.004	6.096	7.000
6 ROM	106-250 um	80.000		1.004	6.096	7.000
7 SAG Discharge	Bulk		370.612	1.004	6.096	7.000
8 SAG Discharge	0-20 um	15.049		1.004	6.096	7.000
9 SAG Discharge	20-37 um	9.654		1.004	6.096	7.000
10 SAG Discharge	37-74 um	16.405		1.004	6.096	7.000
11 SAG Discharge	74-106 um	10.780		1.004	6.096	7.000
12 SAG Discharge	106-250 um	48.112		1.004	6.096	7.000
13 Cyclone UF	Bulk		258.612	1.004	6.096	7.000

Fig. 9. Experimental Data – Measurement Data.

51.4.3. Reviewing and complementing the data

In this part, the idea is to inspect the data and get an understanding of what values will be available after balancing. Also, the data status before balancing is reviewed here and can be changed. Thus changes are reflected in the status after balancing.

The status indications are:

- Stream:**
 - Missing: no data
 - Complete: all variables have data

- Partial: some variables have data
- Variable:
 - Missing: no data
 - Measured: data existing
 - Guesstimated: data are a user-given guesstimation; high uncertainty is set automatically for this The guesstimation is given in the property **User value**
 - Fixed: the user sets including the value that you do not wish to change during the balancing. However, the fixed value may change during balancing because the fixing is done by setting the uncertainty to small. The fixed value is given in the property **User value**
 - By Equation: stream total solids can be set to be a multiple of another stream
 - Excluded: data will not be included in the calculation
- After Balancing:
 - Balanced: solved using data reconciliation
 - Calculated: calculated based on unit material balance
 - Non Available: data are also missing after balancing

The status indications can be changed by clicking the data table cell (dropdown menu) or from the property panel on the right.

The balance equations for the units can be reviewed by clicking the upper bar button shown.

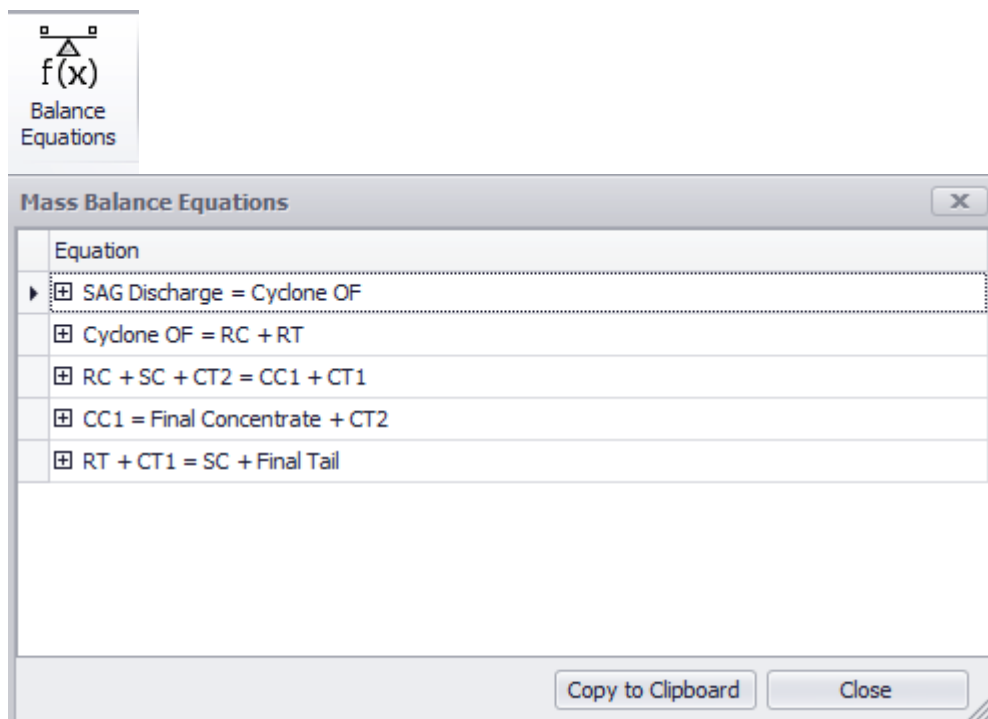


Fig. 10. Opening and reviewing the balance equations.

1. View by streams

The data are presented in a pivot table where the stream is the major column. The data status is shown in pie charts.

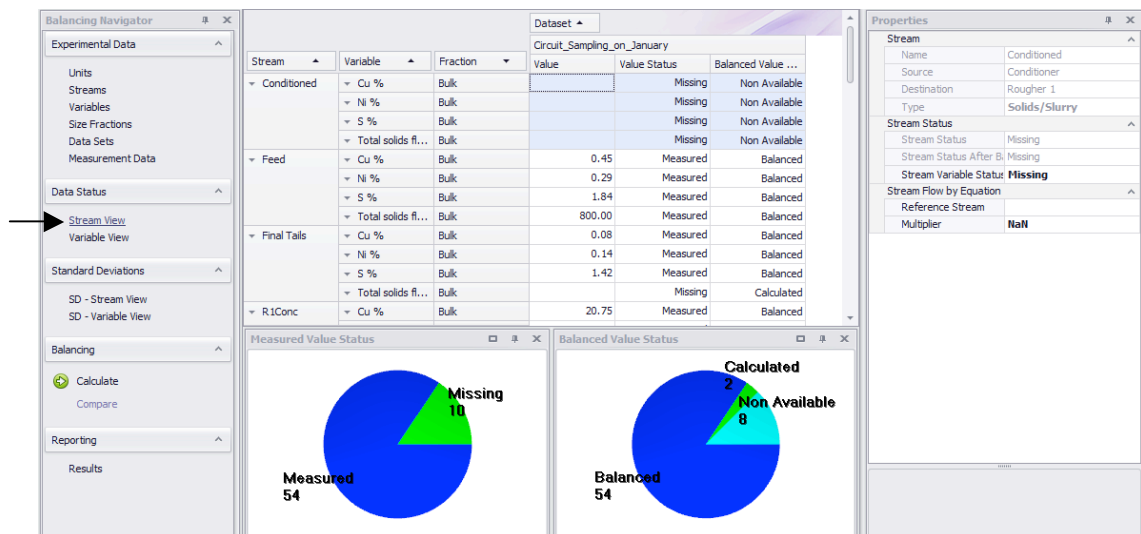


Fig. 11. Data Status – Stream View

2. View by variables

The data is presented in a pivot table where the variable is the major column. The data status is shown in pie charts.

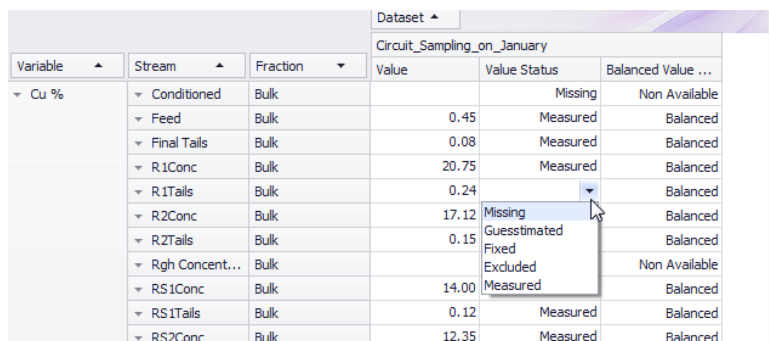


Fig. 12. Data Status – Stream View.

51.4.4. Setting the measurement accuracies

Each assay and piece of raw data is subject to errors. Mass balancing and data reconciliation is meant for adjusting unreliable values, whereas reliable values should be adjusted only a little, if at all. Therefore, the user has to give a value of how reliable each item of raw data is. This is done by defining the error model to give a standard deviation value for the measurement data.

In the HSC Sim 8 Mass Balance tool, the standard deviation can be given using user-friendly pre-settings for the error models.

To define the standard deviations you need to select:

Table 3. Descriptions of error model functions.

Error Model	Parameters	Example
Fixed	Fixed standard deviation as a plain number or fixed relative standard deviation as a negative number or in parentheses	0.1 -5, (5)
$X.x = X\% + 0.x$	The integer is the relative standard deviation; the decimal is the detection limit	10.1
$X\% + 0.1$	Given parameter is the relative standard deviation; 0.1 is the detection limit	6
$10\% + X$	Parameter is the detection limit; relative standard deviation is fixed at 10%	0.05
$a;b;c = \text{MIN}(a\%+b;c)$	a is the relative standard deviation, b is the detection limit, and c is the maximum standard deviation	10;0.01;0.5
$a;b;c=\text{MAX}(a\%+b;c)$	a is the relative standard deviation, b is the detection limit, and c is the minimum standard deviation	10;0.02;0.2
$a;b;c=\%;\text{MIN};\text{MAX}$	a is the relative standard deviation, MIN is the minimum standard deviation, and MAX is the maximum standard deviation	10;
Manual	Standard deviation is given in the data individually for each stream	

1. Standard deviations by streams

The data are presented in a pivot table where the stream is the major column. Standard deviation settings of all variables for that stream can be easily set at once.

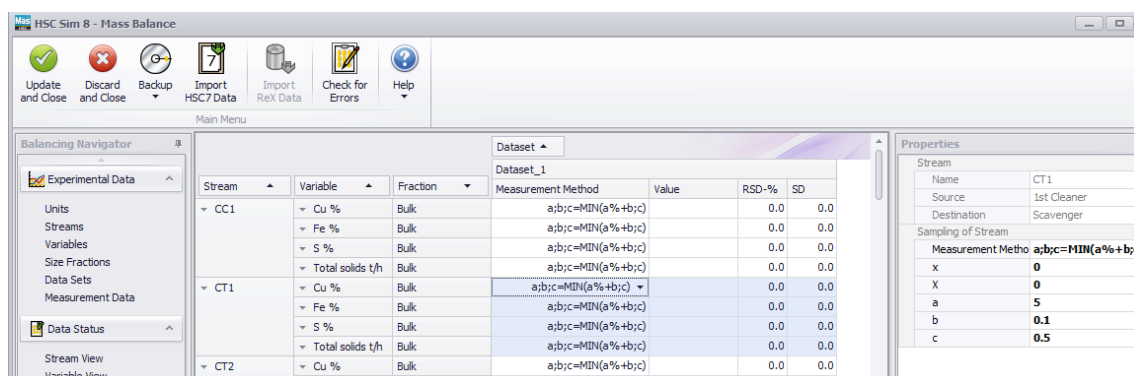


Fig. 13. Standard Deviations – SD – Stream View.

2. Standard deviations by variables

The data are presented in a pivot table where the variable is the major column. Standard deviation settings of all streams for that variable can be easily set at once.

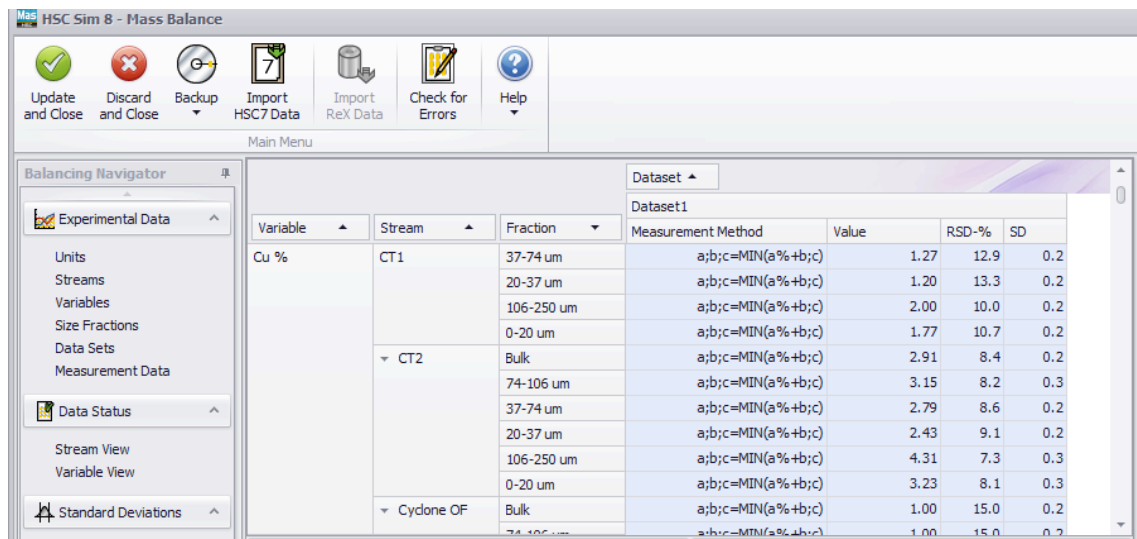


Fig. 14. Standard Deviations – SD – Variable View.

51.4.5. Mass balancing

In the mass balancing upper bar, the following can be selected:

- Sum = 100: if the mineral component sum is required to be 100%.
- Method: LS, NNLS, CLS
- Data to Balance: Assays only, Solids and assays, Solids and water
- PSD Balance: Unsized, Sized, Sized by Assay
- Calculate: runs the data reconciliation

The balancing results can be viewed graphically with, see **Fig. 15**:

- Balance Convergence
- Parity Chart

To solve a mass balance problem, the following mathematical methods are available in the Balance/Report Options on the right-hand side:

- Least Squares Solution (LS)
- Non-negative Least Squares Solution (NNLS)
- Constrained Least Squares Solution (CLS)

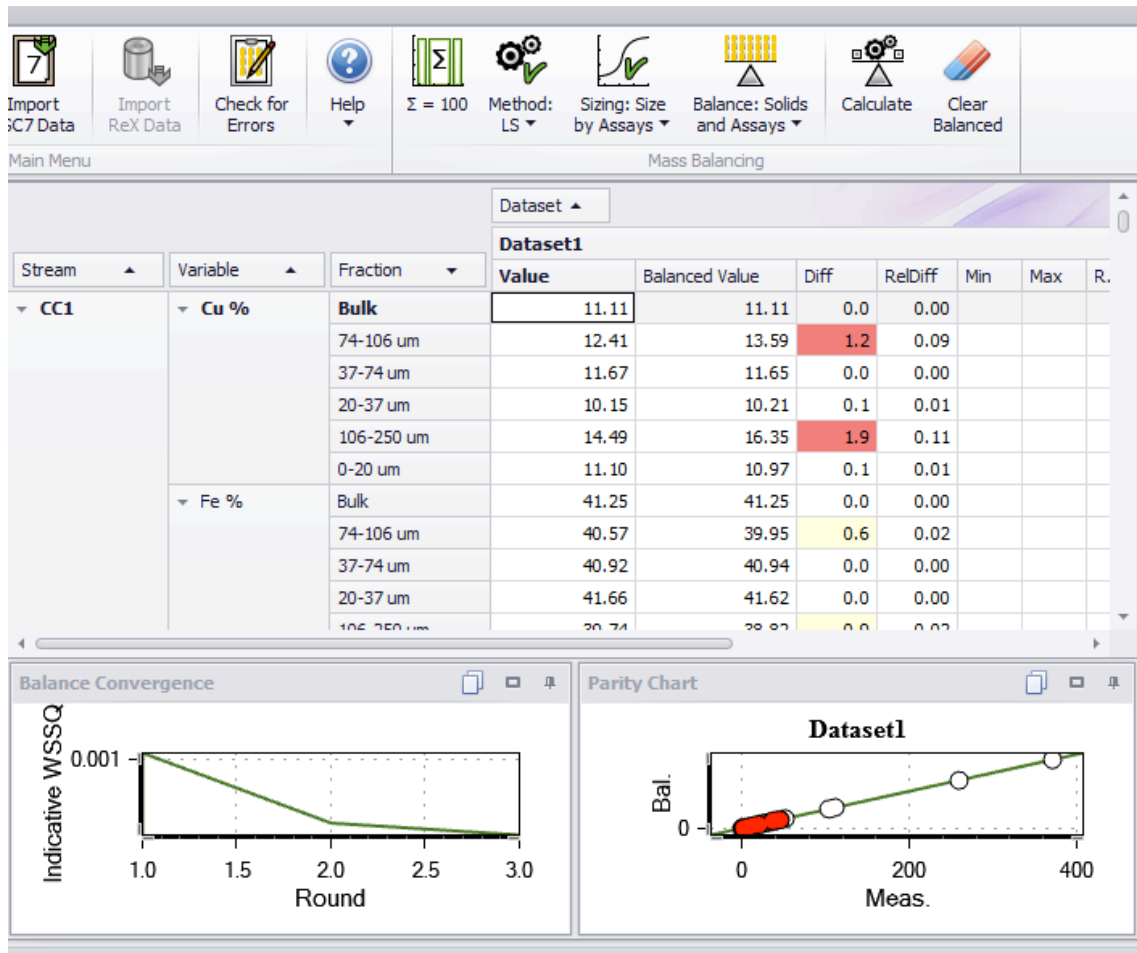


Fig. 15. Balancing – Calculate.

Mass balance problems are solved in two stages: firstly, the total mass flow rates are solved and then the assays are reconciled. In solving the assays, the least squares solution finds the best solution by minimizing the weighted sum of squares, i.e.

$$WSSQ = \sum_{j=1}^k \sum_{i=1}^n \frac{(a_{ij} - b_{ij})^2}{s_{ij}^2} \quad (1)$$

where j refers to the stream, k is the number of streams, i refers to the components (analyses), n is the number of components, a is the measured value, b is the balanced value, and s is the standard deviation.

In non-negative least squares, all 'a's are subject to being non-negative.

In constrained least squares, all 'a's are subject to being between the min. and max.

By clicking dataset you can see the solution parameters Balance tolerance, Max iter and Estimate of null SD in the properties window. Balance tolerance is the condition that defines when the iterations stop and Max iter is the maximum number of iterations. If you don't get reasonable balance you can try to change Estimate of null SD greater.

51.4.6. Reporting and reviewing the results

The screenshot shows the HSC Sim 8 - Mass Balance software interface. The 'Balancing Navigator' on the left lists various data categories. The main window displays a table with columns A through F. The table lists streams and their associated mass balance data.

	A	B	C	D	E	F
1	Streams	Fraction name	Total Solids t/h Meas.	Total Solids t/h Bal.	Cu % Meas.	Cu % Bal.
2	ROM	Bulk	215.000	215.000	0.890	0.872
3	SAG Discha	Bulk				
4	Cyclone UF	Bulk				
5	Cyclone OF	Bulk				
6	RC	Bulk				
7	CC1	Bulk				
8	Final Conce	Bulk		6.076	26.100	26.101
9	RT	Bulk				
10	SC	Bulk				
11	Final Tail	Bulk		208.924	0.120	0.138
12	CT2	Bulk				
13	CT1	Bulk				
14	Mill Water	Bulk				
15	Mill Sump \	Bulk				
16						

Fig. 16. Stream Summary

	A	B	C	D	E	F
1	Variable	WSSQ	DiffTot	RelDif	AVG SD	AVG RSD
2	Total Solids t/h	0.000	0.000	0.000	0.500	0.002
3	Cu %	0.045	0.037	0.136	0.250	0.028
4	Fe %	6.681	1.556	6.429	0.450	0.056
5	S %	0.102	0.222	0.401	0.490	0.027
6						
7	Stream	Sum WSSQ	DiffSum	RelDiffSum	RelDiffAvg	
8	ROM	4.044	0.907	0.393	0.007	
9	SAG Discharge	0.000	0.000			
10	Cyclone UF	0.000	0.000			
11	Cyclone OF	0.000	0.000			
12	RC	0.000	0.000			
13	CC1	0.000	0.000			
14	Final Concentrate	0.002	0.026	0.033	0.019	
15	RT	0.000	0.000			
16	SC	0.000	0.000			
17	Final Tail	2.781	0.882	6.354	0.070	
18	CT2	0.000	0.000			
19	CT1	0.000	0.000			
20	Mill Water	0.000	0.000			
21	Mill Sump Water	0.000	0.000			

Fig. 17. Reporting – Results: Goodness.

	A	B	C	D	E	F	G
1	Units	Equations	Stream	Total Solids	Cu %	Fe %	S %
2	SAG + Cyclone ROM = Final Concentrate + Final Tail						
3	Inputs	ROM		215.000	1.874	14.142	17.653
4	Outputs	Final Conce		6.076	1.586	0.679	2.418
5		Final Tail		208.924	0.288	13.463	15.235
6	Balance			0.00E+00	8.73E-13	-3.62E-11	-5.13E-12
7							

Fig. 18. Reporting – Unit Balance.

51.4.7. Importing HSC7 Excel files

The Excel files to be imported may contain a sheet with flowsheet information (**Fig. 19**). If this sheet is named Flowsheet, the program automatically detects the sheet where the flowsheet information is located. If the name is something else or there is no sheet containing flowsheet information, the name must be specified (**Fig. 23**, Select Flowsheet)

Units	ROM	SAG Discharge	Cyclone UF	Cyclone OF	RC	CC1	Final Concentrate	RT	SC	Final Tail	CT2
SAG	1	-1	1	0	0	0	0	0	0	0	0
Cyclone	0	1	-1	-1	0	0	0	0	0	0	0
Rougher	0	0	0	1	-1	0	0	-1	0	0	0
1st Cleaner	0	0	0	0	1	-1	0	0	1	0	1
2nd Cleaner	0	0	0	0	0	1	-1	0	0	0	-1
Scavenger	0	0	0	0	0	0	0	1	-1	-1	0
Process Waters	0	0	0	0	0	0	0	0	0	0	0

Fig. 19. An Excel sheet containing flowsheet data.

The measurement data is read from a different sheet of the same Excel file. The first column must be named Streams (Cell A1), the second Source (Cell A2), and the third Destination (cell A3) if the data are horizontal (**Fig. 21**). If the data are vertical, the first row must be named Streams (A1), the second row must be named Source (A2), and the third Destination (A3) (**Fig. 20**). Imported vertical data can only be unsized or sized (without analyses).

	A	B	C	D	E	F	G
1	Stream->	ROM	SAG Discharge	Cyclone UF	Cyclone OF	Mill Water	Mill Sump Water
2	Source	?	SAG	Cyclone	Cyclone	Process Waters	Process Waters
3	Destination	SAG	Cyclone	SAG	Rougher	SAG	Cyclone
4	Mass%						
5	Solids Flowrate t/h	517.5	1810	1290	517.5	0	0
6	Water t/h	20	600	520	600	180	200
7	%Solids	96.6	75.7	71.2	44.6	0	0
8	Cu %	1.2	1.22	1.3	1.96	0	0
9	S %	12.4	13.2	14.3	12.5	0	0
10	0-53um	9.7	18.6	11.1	35.9	0	0
11	53-75um	1.8	4.2	2.5	6.9	0	0
12	75-150um	4.6	9.2	6.5	18.3	0	0
13	150-300um	5.6	17.1	16.5	21.2	0	0
14	300-600um	6.8	19.7	23.2	13.5	0	0
15	600-850um	3.3	7.8	10.3	2.2	0	0
16	850-1180um	4.5	5.3	7.2	1.2	0	0
17	1180-2360um	9.4	6.6	9.6	0.7	0	0
18	2360-4750um	19.5	5.8	7	0	0	0
19	4750-9500um	30.5	4.7	5.1	0	0	0
20	9500-13200um	3.4	0.9	1	0	0	0
21	13200-20000um	0.9	0.2	0	0	0	0

Fig. 20. Vertical sized data (without analyses).

	A	B	C	D	E	F	G	H	I	J	K	L
1	Stream	Source	Destination	Solids Recovery%	Total	Solids t/h	Fraction	nc	Fraction	nam	Fraction	m%
2	ROM	?	SAG		225	0	Bulk				1.040122	6.786279
3	SAG Discharge	SAG	Cyclone		225	0	Bulk				0.989001	6.836096
4	Cyclone UF	Cyclone	SAG		225	0	Bulk				1.040242	7.127088
5	Cyclone OF	Cyclone	Rougher		225	0	Bulk				0.989115	7.379699
6	RC	Rougher	1st Cleaner		0	0	Bulk				12.4814	41.66124
7	CC1	1st Cleaner	2nd Cleaner		0	0	Bulk				10.9394	48.75182
8	Final Concentrat	2nd Cleaner	?		0	0	Bulk				15.75383	48.01802
9	RT	Rougher	Scavenger		0	0	Bulk				0.193961	4.137773
10	SC	Scavenger	1st Cleaner		0	0	Bulk				4.303134	43.78948
11	Final Tail	Scavenger	?		0	0	Bulk				0.051718	4.474968
12	CT2	2nd Cleaner	1st Cleaner		0	0	Bulk				3.009419	51.93595
13	CT1	1st Cleaner	Scavenger		0	0	Bulk				1.427522	40.93256

Fig. 21. Horizontal unsized data.

The program automatically detects a sheet named Streams as the sheet where the measurement data can be found. If the name of the sheet containing the measurement data is not Streams, the user should tell the program where the measurement data can be found (Fig. 23, Analyses)

The following screenshots show how an HSC7 file is imported. Importing an HSC7 file is started by clicking Tools-Mass Balancing and then clicking the Import HSC7 Data button (Fig. 22). After that a dialog will open (Fig. 23).

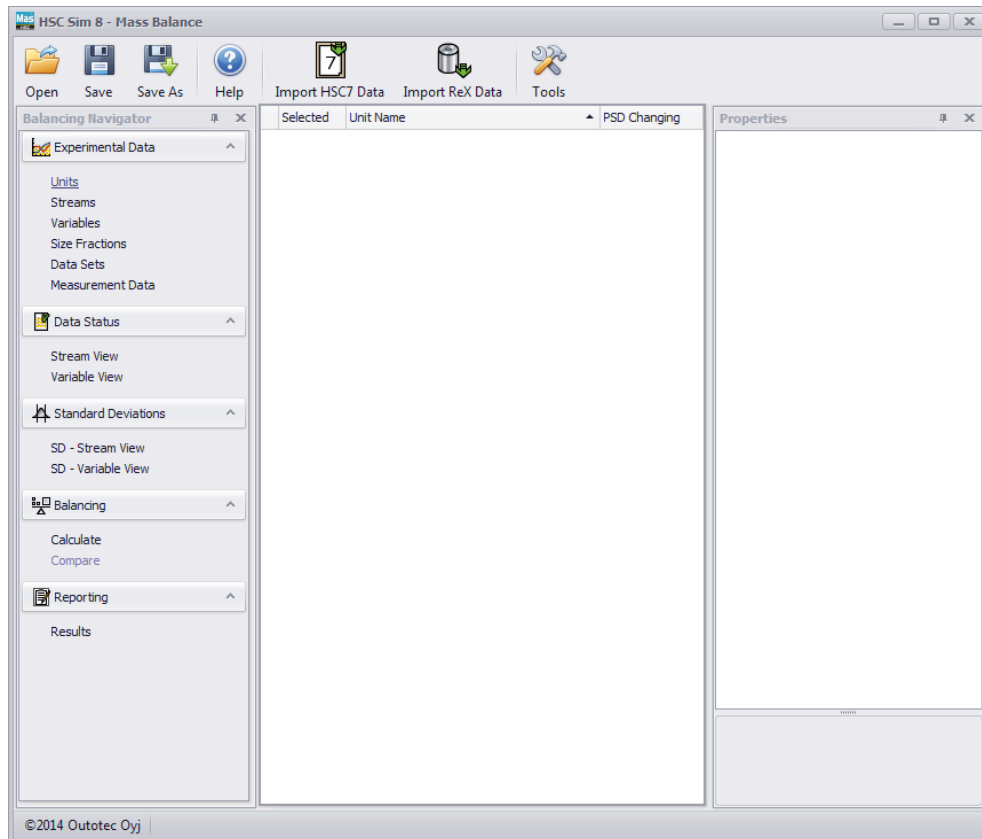


Fig. 22. Import HSC7 Data.

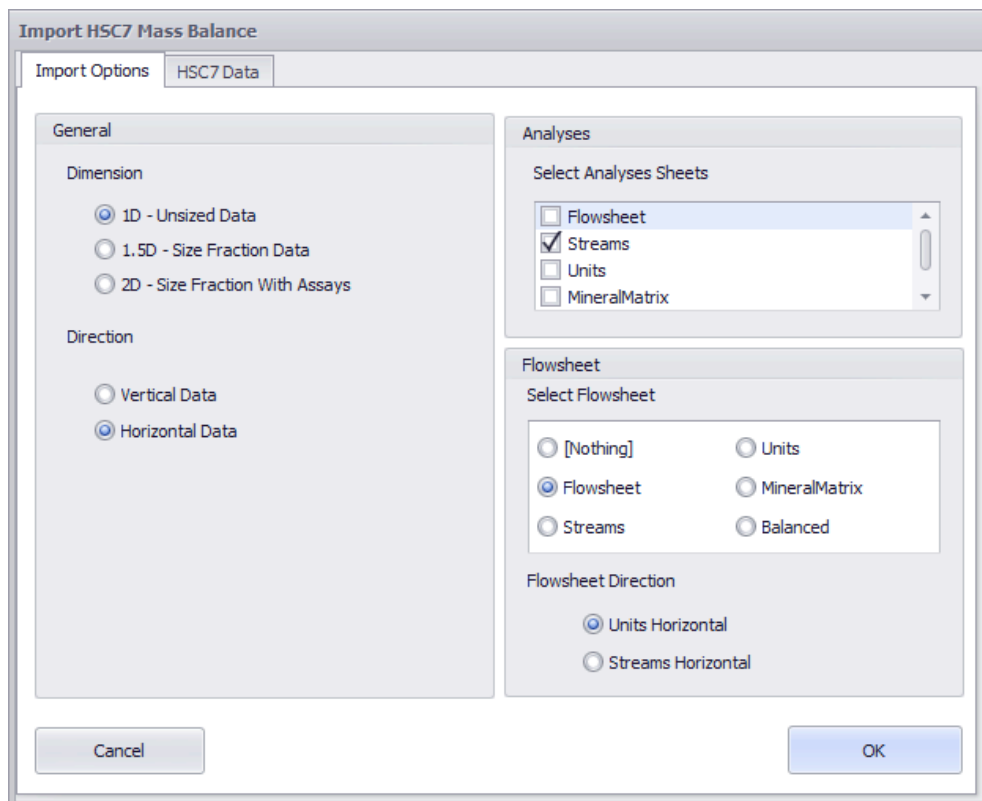
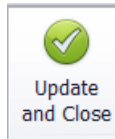
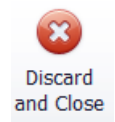


Fig. 23. Import HSC7 Data Dialog.

51.5. Mass balance buttons and dropdowns



Update and save changes to HSC Sim flowsheet and close



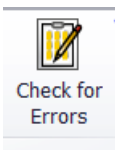
Discard changes and close HSC mass balance



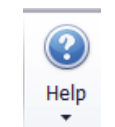
Open/Save backup (HSCMas file) of the mass balance



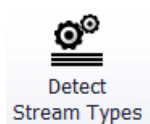
Import existing HSC7 mass balance data (analyses.xls)



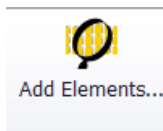
Error check



Help and examples



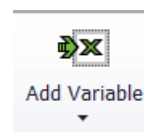
Detects stream types automatically for Solid/slurry and Liquid based on the data. If there are streams with no data the stream type is set as Unknown. The user should either uncheck these Unknown streams or set the types manually















Select elements from periodic table

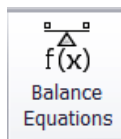


Select minerals from HSC database

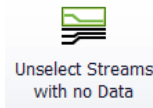


Add new variable

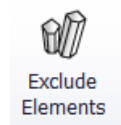
 Remove Variable	Remove the selected variable
 Add Size Fraction	Add a new sieve size
 Add Data Set	Add a new data set
 Remove Data Set	Remove the selected data set
 Flip Table	Transpose streams and variables
 Copy	Copy the whole table
 Paste Experimental Data	Paste data to correct places based on the stream and variable names
 Element to Mineral...	Element to mineral conversion using HSC Geo
 View Mineral Matrix	View minerals and their compositions
 Sol-% to Water	Converts solids percentage measurements to water flow rates
 Back Calculate Missing Values	Back calculate missing data if possible
 Clear Back Calculated Values	Clear back calculated missing data



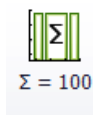
View the mass balance equations



Unselect the streams without data



Exclude all elements (A) and do balancing with minerals (M)



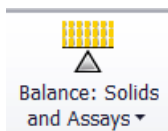
Set component sum=100 when balancing minerals



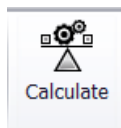
Select calculation method. The available methods are LS, NNLS, and CLS



PSD balance: Possible selections are Unsize, Size and Size by Assays



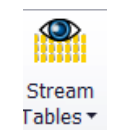
Select the data to be balanced



Calculates mass balance



Clears the mass balancing results



Create or update HSC Sim stream tables

51.6. Error check messages

1. Dataset: No Active dataset found
 - Please contact the developers
2. Units: No selected units found
 - At least one unit should be selected
3. Streams: No selected streams found
 - Some of the streams should be selected
4. Units: No input stream
 - Found a unit with no input streams
5. Units: No output stream
 - Found a unit with no output streams
6. Streams: Source and destination missing
 - Found a stream with no source and destination
7. Fractions: Bulk not found
 - Please contact the developers
8. Data: No data found
 - Add data in the measurement data view
9. Variables: Total solids measurement missing
 - There should be exactly one selected variable of the Total Solids type
10. Variables: Too many variables of the type total solids
 - There should be exactly one selected variable of the Total Solids type
11. Variables: No selected assays found
 - There should be at least one selected variable of the Mineral Assay or Solids Component Assay type
12. Streams: All stream types unknown
 - Go to Streams and press Detect Stream Types button or set the stream types manually
13. User Values: UserValues missing
 - ValueStatus of some data is set to Fixed or Questimated but the UserValue is not given
14. Stream Types: Unknown found
 - Go to Streams and press Detect Stream Types button or set the stream types manually
15. Variables: Size Fraction wt % variable missing
 - There should be exactly one variable of the type Size Fraction wt %
16. Variables: Too many variables of the type Size Fraction wt-%
 - There should be exactly one variable of the type Size Fraction wt %
17. Units: No combined units found
 - There can be several reasons why combined units cannot be formed. There may be too many missing measurements or there may be errors in the flowsheet.
18. Notification: Min or Max values detected: It is recommended to use the CLS method

51.7. Mathematics and algorithms

In this section, the main algorithms and methods for data reconciliation in HSC Chemistry® 8 are briefly summarized.

Definitions

N_{F1}	=	number of flows, unsized
N_{F2}	=	number of flows, sized, sized by assay
N_U	=	number of units
N_{SRU}	=	number of size-reducing units (PSD changing unit)
N_{SF}	=	number of sub-flows
N_E	=	number of chemical elements
G	=	grade of chemical element
G^M	=	measured grade of chemical element
F	=	solids flow rate
F^M	=	measured solids flow rate
W	=	water flow rate
W^M	=	measured water flow rate
P_c	=	%solids = $F \cdot 100 / (F + W)$
P_c^M	=	measured %solids
M	=	fraction m% = $F_{flow,subflow} \cdot 100 / F_{flow}$
M^M	=	fraction m% measurements

$$e_{flow}^{unit} = \begin{cases} 1, & \text{the flow enters the unit} \\ -1, & \text{the flow exits the unit} \\ 0, & \text{otherwise} \end{cases}$$

51.7.1. Unsized (bulk) mass balance

In the *unsized (bulk)* mass balance solution, solids and water flow rates are solved first. After that the bulk analyses are solved. During the calculation: 1) the solids flow rates are solved first and after that 2) the water flow rates are solved.

1. Bulk flow rates

The equations for solving the bulk solids flow rate are:

mass balance Equations (2)

$$\sum_{flow=1}^{N_{F1}} e_{flow}^{unit} \cdot F_{flow,tot} = 0 \quad unit = 1, \dots, N_U \quad (2)$$

analyses Equation (3)

$$\sum_{flow=1}^{N_{F1}} e_{flow}^{unit} * G_{flow,tot,chemical_element}^M * F_{flow,tot} \approx 0 \quad unit = 1, \dots, N_U \quad (3)$$

$$chemical_element = 1, \dots, N_E$$

solids flow rate measurements (4)

$$F_{flow,tot} \approx F_{flow,tot}^M \quad flow = 1, \dots, N_{F1} \quad (4)$$

The equations for solving the bulk water flow rate are:

mass balance Equations (5)

$$\sum_{flow=1}^{N_{F1}} e_{flow}^{unit} * W_{flow,tot} = 0 \quad unit = 1, \dots, N_U \quad (5)$$

water flow rate measurements Equation (6)

$$W_{flow,tot} \approx W_{flow,tot}^M \quad flow = 1, \dots, N_{F1} \quad (6)$$

% solids measurements (7)

$$(Pc^M / 100) * W_{flow,tot} \approx F_{flow,tot} - (Pc^M / 100) * F_{flow,tot} \quad flow = 1, \dots, N_{F1} \quad (7)$$

Mass balance Equations (2) and (5) are the equality constraints for the solutions. The solution method used is element-wise weighted total least squares². The weights are standard deviations of the solids flow rate measurements F^M , the analyses G^M , the water flow rate measurements W^M , and the %solids measurements Pc^M . The flow rates can be solved without any constraints (LS), subject to non-negativity constraints (NNLS)³, and subject to simple bounds

$$lb1 \leq F \leq ub1$$

$$lb2 \leq W \leq ub2$$

(CLS)⁴.

2. Bulk analyses

Let G and G_M be $N_{F1} \times N_E$ matrices. The operator vec stacks the matrix columns into a vector.

The equations for the analyses solution are:

measurements (8)

$$vec(G) \approx vec(G^M) \quad (8)$$

mass balance Equations (9) for the analyses:

$$vec(B * G) = 0 \quad (9)$$

where the $N_U \times N_{F1}$ matrix B is defined:

$$B_{unit,flow} = e_{unit}^{flow} * F_{flow,tot} \quad (10)$$

If the option minerals sum=100 is selected, the following Equations (11) are included:

$$\sum_{chemical_element=1}^{N_E} G_{flow,tot,chemical_element} = 100 \quad flow = 1, \dots, N_{F1} \quad (11)$$

Equations (9) and (11) are the equality constraints for the solution. The solution method used is weighted least squares 1). If Equations (11) are included in Equations (9), the matrix B is $(N_U - 1) \times N_{F1}$ to avoid linear dependency of equality constraints.

As before, the analyses can be solved without any constraints (LS), subject to non-negativity constraints (NNLS), and subject to simple bounds (CLS). If there are no constraints, the minimal maximum norm solution can be calculated (LS, MinMax)⁵.

51.7.2. Sized mass balance (without sized analyses)

Sized mass balance differs from *unsized (bulk)* solution in that the fraction m% is solved and the fraction m% measurement is used in the solution of total flows. *Sized* differs from *Size by Assay* in that the analyses are not given and the number of flows is the same as in the *unsized* case.

1. Total flow mass balances of the streams

Firstly, the total flows are solved. The Equations are:

mass balance Equations (12)

$$\sum_{flow=1}^{N_{F1}} e_{flow}^{unit} * F_{flow,tot} = 0 \quad unit = 1, \dots, N_U \quad (12)$$

fraction m% measurements (13)

$$\sum_{flow=1}^{N_{F1}} e_{flow}^{unit} * M_{flow,subflow}^M * F_{flow,tot} \approx 0 \quad unit = 1, \dots, N_U - N_{SRU} - 1 \quad (13)$$

$$subflow = 1, \dots, N_{SF}$$

Units are indexed up to $N_U - N_{SRU} - 1$ to avoid linear dependency of equality constraints.

Flow measurements (14)

$$F_{flow,tot} \approx F_{flow,tot}^M \quad flow = 1, \dots, N_{F1} \quad (14)$$

If 1D analyses are given, the following Equations are included:

analyses (15)

$$\sum_{flow=1}^{N_{F1}} e_{flow}^{unit} * G_{flow,tot,chemical_element}^M * F_{flow,tot} \approx 0 \quad unit = 1, \dots, N_U \quad (15)$$

$$chemical_element = 1, \dots, N_E$$

Equations (12) are equality constraints for the solution. The solution method used is element-wise weighted total least squares. The weights are standard deviations of the solids flow rate measurements F^M , the analyses G^M and fraction m% M^M .

As before, the flow rates can be solved without any constraints (LS), subject to non-negativity constraints (NNLS), and subject to simple bounds (CLS). If there are no constraints, the minimal maximum norm solution can be calculated (LS, MinMax)⁵.

2. Size fraction flow mass balance

Then the %m values of the sub-flows are solved. The equations are:

fraction m% measurements (16)

$$M_{flow,subflow} \approx M_{flow,subflow}^M \quad (16)$$

mass balance equations (17)

$$\sum_{flow=1}^{N_{F1}} e_{flow}^{unit} * M_{flow,subflow} * F_{flow,tot} = 0 \quad \begin{array}{l} unit = 1, \dots, N_U \quad unit \text{ not size reducing} \\ subflow = 1, \dots, N_{SF} \end{array} \quad (17)$$

sum fraction m% is a hundred (18)

$$\sum_{i=1}^{N_{SF}} M_{flow,subflow} = 100 \quad (18)$$

Equations (17) and (18) are equality constraints. The solution method used is element-wise total least squares and %m values can be solved without any constraints (LS), subject to non-negativity constraints (NNLS), and subject to simple bounds (CLS).

3. Bulk analyses

If the unsized bulk analyses are given, the balanced analyses are calculated as described above (see: unsized mass balance).

51.7.3. Sized by assay mass balance

Before a *sized by assay* mass balance solution, the *unsized* or *sized* mass balance must be solved first. The results $F_{flow,tot}$ of the *unsized* or *sized* solution are used in the *sized by assay* solution. In a *sized by assay* solution, the size fraction sub-flows are calculated first and after that the analyses are solved.

1. Sized by assay fraction sub-flows

The equations for size by assay sub-flow solutions are:

mass balance Equations (19) for each unit that is not size reducing

$$\sum_{flow=1}^{N_{F2}} e_{flow}^{unit} * F_{flow,subflow} = 0 \quad \begin{array}{l} unit = n_1, \dots, n_{NU-1} \quad unit \text{ not size reducing} \\ subflow = 1, \dots, N_S \end{array} \quad (19)$$

Above n_i is the index of the i th unit that is not size reducing. Units are indexed up to $N_U - 1$ to avoid linear dependency of equality constraints.

Sum of sub-flows is the total flow (20)

$$\sum_{subflow=1}^{NS} F_{flow,subflow} = F_{flow,tot} \quad flow = 1, \dots, N_{F2} \quad (20)$$

Analyses for each unit that are not size reducing (21)

$$\sum_{flow=1}^{N_{F2}} e_{flow}^{unit} * G_{flow,chemical_element,subflow} * F_{flow,subflow} \approx 0 \quad (21)$$

$unit = n_1, \dots, n_{NU}$ unit not size reducing
 $chemical_element = 1, \dots, N_E$
 $subflow = 1, \dots, N_S$

Fraction %m measurements (22)

$$F_{flow,subflow} \approx M_{flow,subflow}^M * F_{flow,tot} / 100 \quad (22)$$

$flow = 1, \dots, N_{F2}$
 $subflow = 1, \dots, N_S$

or alternatively

flow measurements (23)

$$F_{flow,subflow} \approx F_{flow,subflow}^M \quad (23)$$

$flow = 1, \dots, N_{F2}$
 $subflow = 1, \dots, N_S$

The solution method used is element-wise weighted least squares. The equations can be solved without any constraints (LS), subject to non-negativity constraints (NNLS), and subject to simple bounds (CLS).

2. Sized by assay fraction analyses

Let G and G^M be $N_{F2} \times N_S \times N_E$ matrices. The operator vec stacks the matrix columns into a vector.

The equations for the analyses solution are:

$$vec(G) \approx vec(G^M) \quad (24)$$

mass balance equations (25) for the analyses

$$vec(B * G) = 0 \quad (25)$$

where the $(N_S - 1) \times (N_U - N_{SRU}) \times (N_{F2} \times (N_S - 1))$ matrix B is defined

$$B = diag(B^{subflow}) \quad subflow = 1, \dots, N_S - 1 \quad (26)$$

Sub-flows are indexed up to $N_S - 1$ to avoid linear dependency of equality constraints. Where the operator *diag* adds matrices $B^{subflow}$ at the diagonal of the matrix B and

$$B_{unit,flow}^{subflow} = e_{flow}^{unit} * F_{flow,subflow} \quad (27)$$

the sum of sub-flows is the total flow (28)

$$\sum_{subflow=1}^{NS} F_{flow,subflow} * G_{flow,chemical_element,subflow} = F_{flow,tot} * G_{flow,tot,chemical_element} \quad (28)$$

$$flow = 1, \dots, N_{F2}$$

$$chemical_element = 1, \dots, N_E$$

If the option minerals sum=100 is selected, the following Equations (29) are included:

$$\sum_{chemical_element=1}^{N_E} G_{flow,chemical_element,subflow} = 100 \quad flow = 1, \dots, N_{F1} \quad (29)$$

$$subflow = 1, \dots, N_S$$

If Equations (29) are included, B is $(N_S - 1) * (N_U - N_{SRU} - 1) \times (N_{F2} * (N_S - 1))$ to avoid linear dependencies.

The solution method used is weighted least squares. The equations can be solved without any constraints (LS), subject to non-negativity constraints (NNLS), and subject to simple bounds (CLS).

51.8. References

1. Golub, van Loan: Matrix Computations, Third edition 1996
2. Markovsky, Rastello, Premoli, Kuhush, van Huffel: The element-wise weighted total least squares problem, Computational Statistic & Data Analysis 50 (2006) pp.181-209
3. Lawson, Hanson: Solving Least Squares Problems, 1974
4. Haskell, Hanson: An Algorithm for Linear Least Squares Problems with Equality and Nonnegativity Constraints, Mathematical Programming 21 (1981), pp.98-118
5. Barrodale, Phillips: Algorithm 495, Solution of an Overdetermined System of Linear Equations in the Chebyshev Norm, ACM Transactions on Mathematical Software, Vol 1, No 3, September 1975, pp. 264-270.