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49. MASS BALANCING AND DATA RECONCILIATION EXAMPLES

This manual gives examples how to solve different kind of mass balancing problems. Please have a look of the manual "48. Sim Mass Balancing" for detailed information of different buttons and menus.

49.1. Mass Balancing and Data Reconciliation

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

HSC7 allows the user to solve the following mass balance problems (Table 1):

1. Reconcile measured or estimated component flowrates (1D components).
2. Mass balance and reconcile chemical analyses (1D assays)
3. Mass balance minerals in minerals processing circuit (1D Minerals)
4. Mass balance size distribution and water balance (1.5D)
5. Mass balance assays and components in 2- or 3-phase systems where the bulk composition is not analyzed (2D Components)
6. Mass balance minerals or chemical assays size-by-size (2D Assays)
7. Mass balance particles, MLA assays (3D)

This manual includes mass balance and data reconciliation examples of following problems:

1. 1D Components (chapter 49.2)
2. 1D assays (chapter 49.3)
3. 1D minerals (chapter 49.4)
4. 1.5D (chapter 49.5)
5. 2D analyses (chapter 49.6)
6. Multiple data sets (chapter 49.7)

*Table 1. Mass balance cases that can be solved with HSC Sim. The red **X** indicates that data is necessary and defines the case. In order to solve the 3D-mass balance, the particle tracking module of HSC is required. This is currently available only for AMIRA P9O Sponsors.*

Assayed or estimated values | Case	1D Components	1D Assays	1D Minerals	1.5D	2D Assays	2D Minerals	3D
Total stream flowrates	X						
Total solid flowrates	X	X	X	X	X	X	X
Liquid flowrates	X				(X)	(X)	(X)
Component flowrates	**X**						
Component distributions	X						
%Solids		(X)	(X)	(X)	(X)	(X)	(X)
Bulk chemical compositions		**X**	X		X	X	X
Minerals and their chemical composition			**X**			**X**	X
Particle size distribution				**X**	X	X	X
Chemical composition of size fractions					**X**	**X**	X
Particles (MLA data)							**X**

49.2. Example 1 - 1D Components

The 1D components balancing exercise can be found in C:\HSC7\Flowsheet_MassBalancing\Example 1D Components. To jump over the drawing and bringing the experimental data just open the "1D Component Example.fls" file.

In this exercise we have a circuit with five units and eleven streams. We want to get the balance for arsenic and copper flowrates through the circuit. We have measured the flowrate information only from the input and output streams. In addition we have the knowledge on the distribution of the component between the output streams of each of the unit. This data could be metallurgical knowledge of specific process stages.

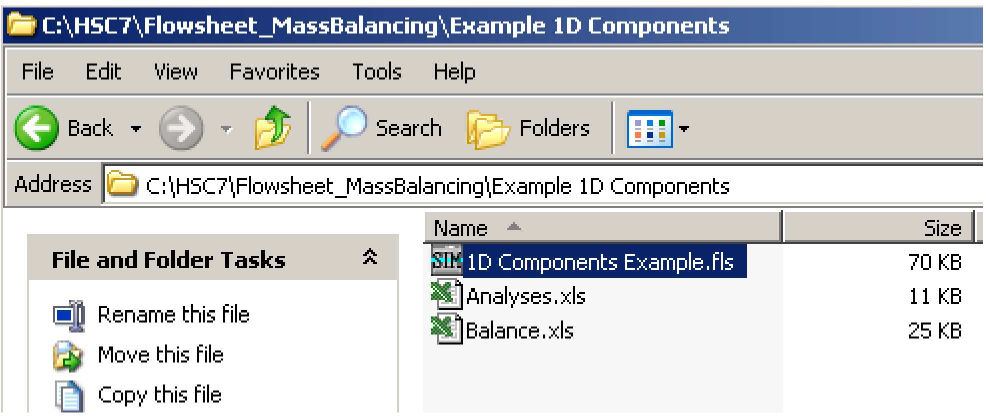


Figure 1. Example 1D can be found in your computer.

49.2.1. Draw the flowsheet

Open HSC Sim.

1. Turn the HSC mode to Experimental (Figure 2)
2. Draw first the units; the example has five units named as U1, U2, U3, U4 and U5 (Figure 3)
3. Draw the streams; the example has eleven streams called as letters form A to J. Be sure that the Source and Destinations are correct (Figure 3)
4. Finally check the stream connections using the “Overlay and Route Check” button as shown below. The input streams are shown blue, the output streams red and the intermediate streams black .
5. Save the drawing.

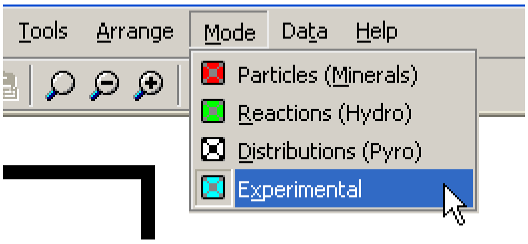


Figure 2. Turning the mode to Experimental.

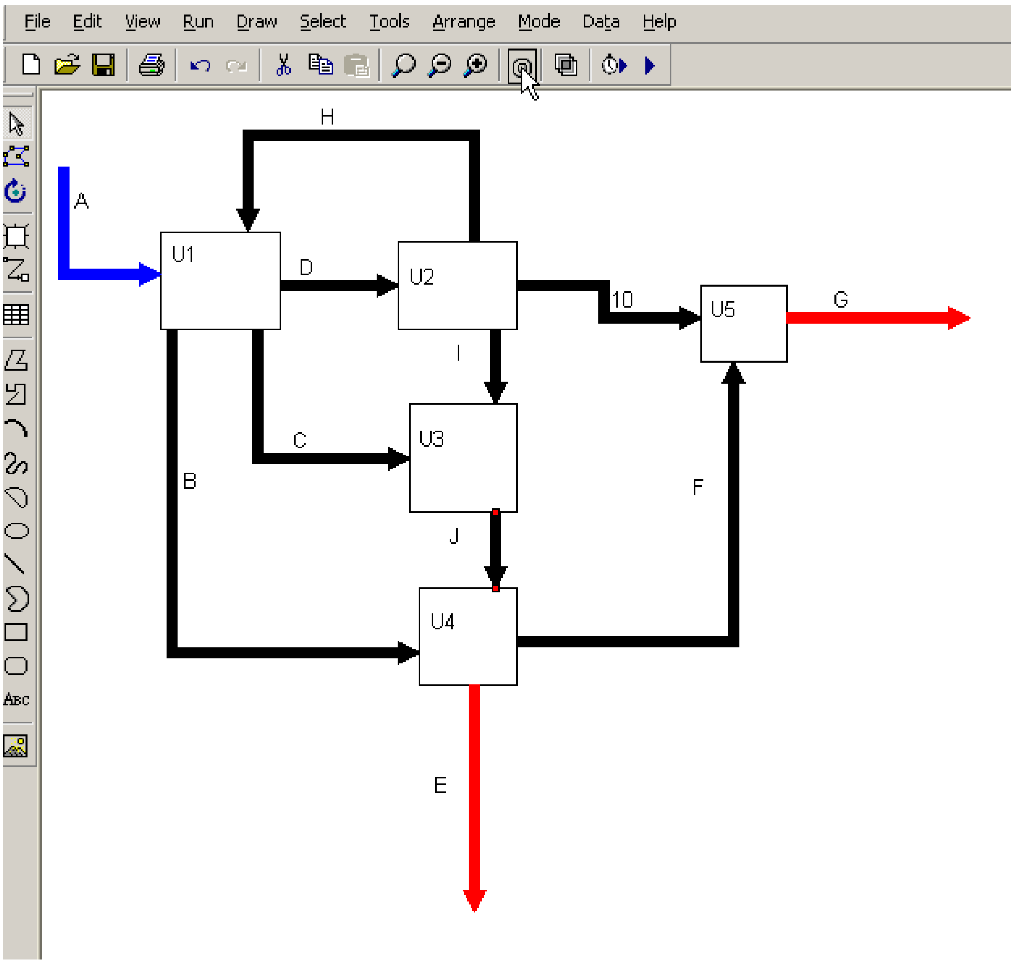


Figure 3. Flowsheet of Example 1.

49.2.2. Bring in the experimental data

The experimental data is collected in the Analyses.xls file which is to be stored in the very same folder you saved the flowsheet drawing file. To import the data using Excel:

1. Open the Analyses.xls file in MS Excel.
2. In HSC go to the Analyses window (Experimental – Analyses, Figure 4). Create Stream Properties sheet: Select from the menu "Create – Stream Properties Sheet – Horizontal" (Figure 6)
3. In the MS Excel copy the experimental data into the clipboard. The cell "Stream" must be the first cell on top left (Figure 6).
4. In HSC Sim go to the Experimental data and select Edit – Paste Special – Assays" (Figure 7).
5. To visualize the data in the flowsheet create the value labels: press Visualize and select "Create Stream Value Labels" (Figure 8).
6. In the Analyses window select column to visualize the variable in the flowsheet (Figure 9).

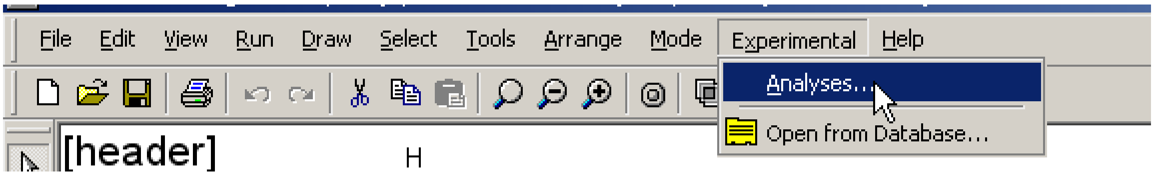


Figure 4. Experimental data.

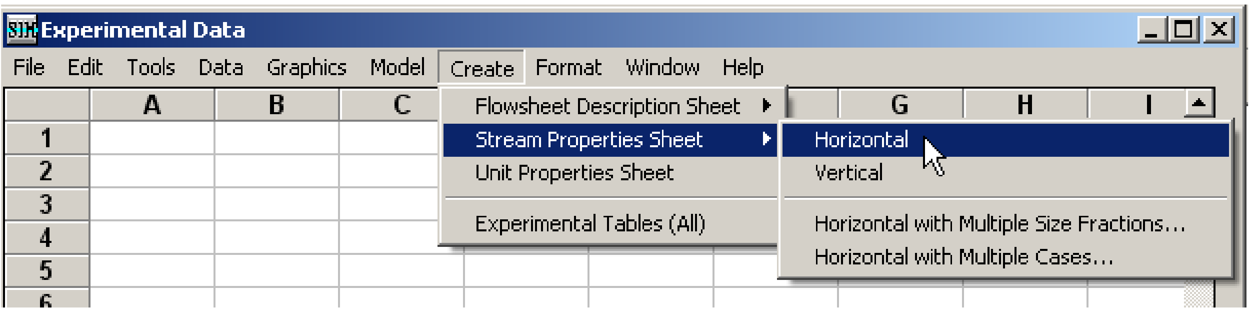


Figure 5. Creating Stream Properties Sheet.

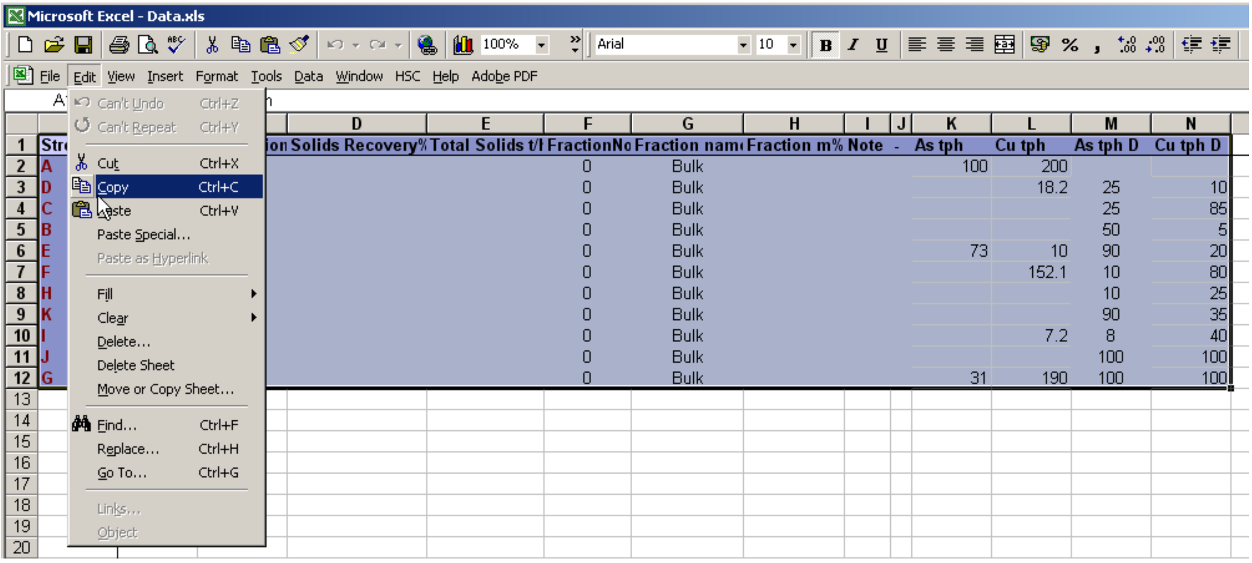


Figure 6. Copying data into clipboard. The first cell on left top corner has to be the "Stream" cell.

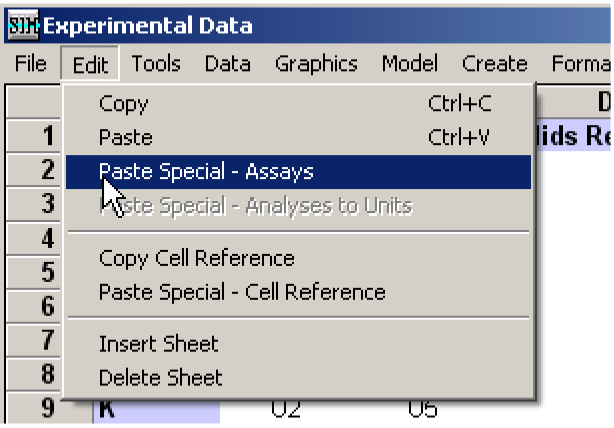


Figure 7. Pasting assays.

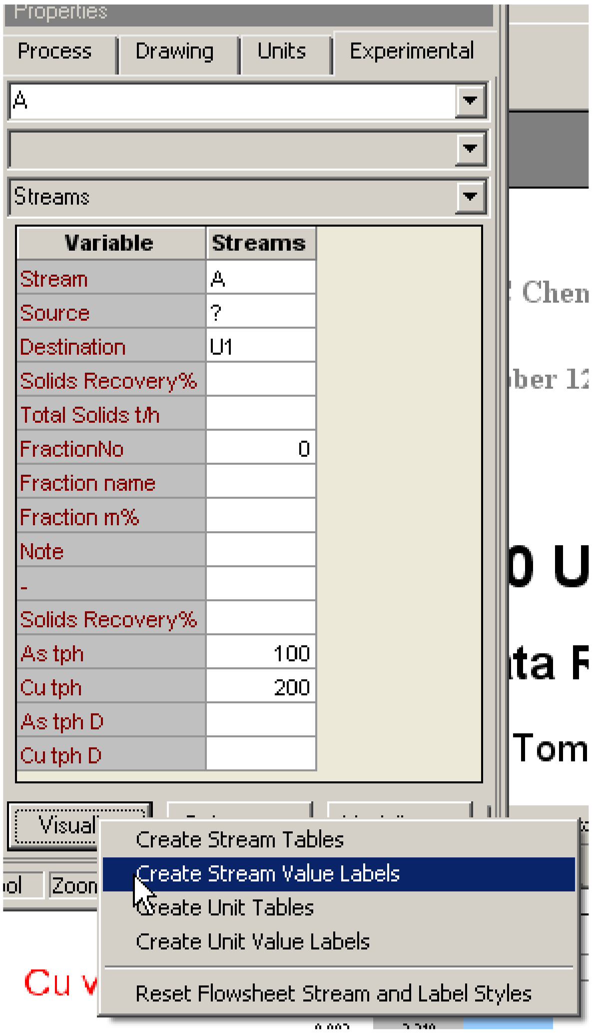


Figure 8. Creating Stream Value Labels.

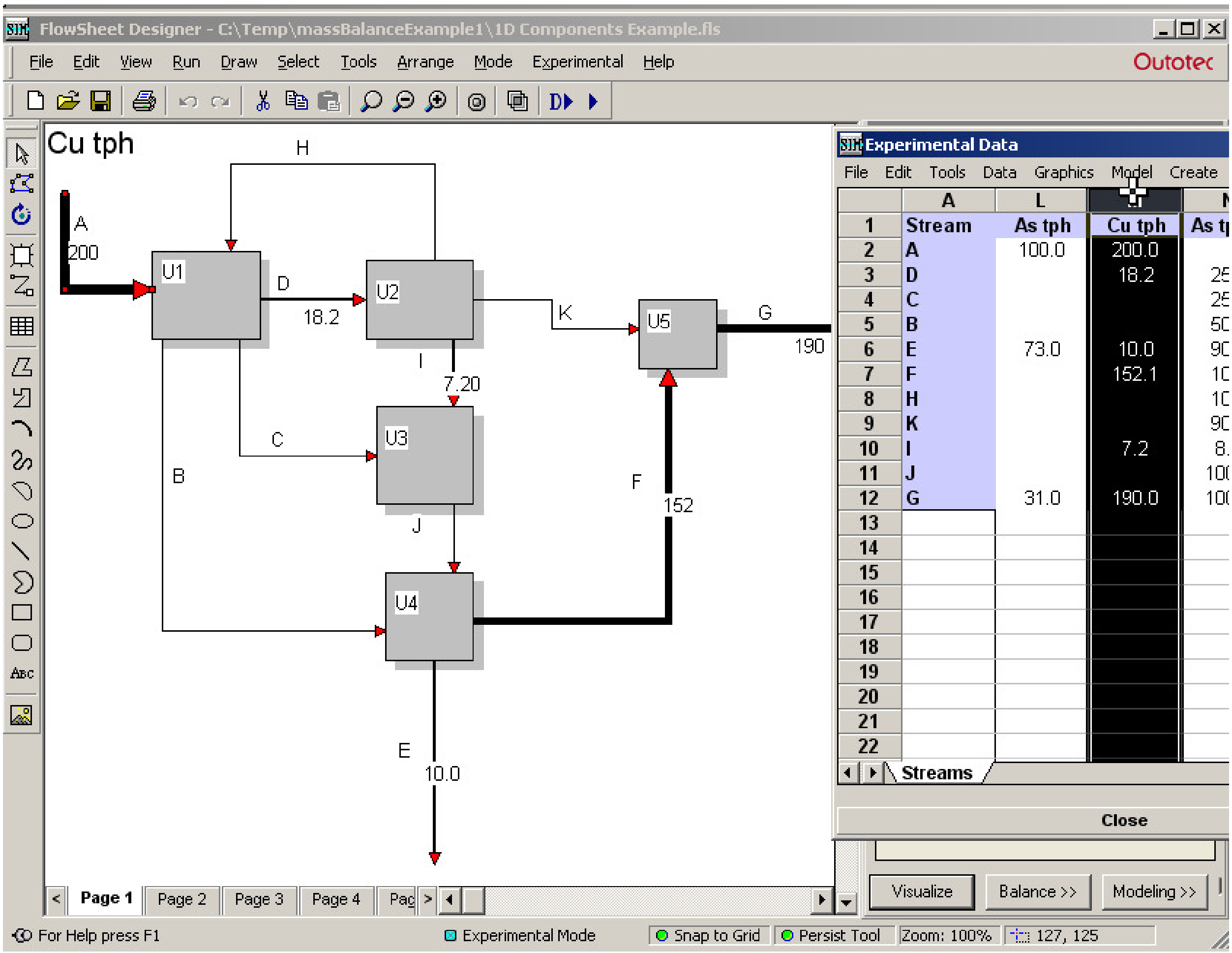


Figure 9. Visualizing variable in the flowsheet.

49.2.3. Mass Balancing Wizard

To mass balance the data:

1. Press “Mass Balancing and Data Reconciliation>>>” in the Analyses – window (Figure 10).
2. Check that As and Cu flowrates are identified correctly as “CD – Component Flowrates” and As and Cu distributions as “CD – Component Distribution” (Figure 11). Press Next.
3. In the second wizard window (step 2 of 5) check that all streams are selected for the mass balancing (Figure 12). Press Next.
4. In the Step 3 you can edit the error models. Here we use the default values, i.e. flowrates the relative error is 10%, detection limit is 0.1 and max standard deviation is 10 tph. For distribution the relative error is 10%, detection limit 1% and max standard deviation is 10 percentage values. (Figure 13). Press Next.
5. Step 4; the reference stream is “A”. Press Next (Figure 14).
6. Step 5. Errors and mass balance nodes. There should not be any errors. Press Next (Figure 15).

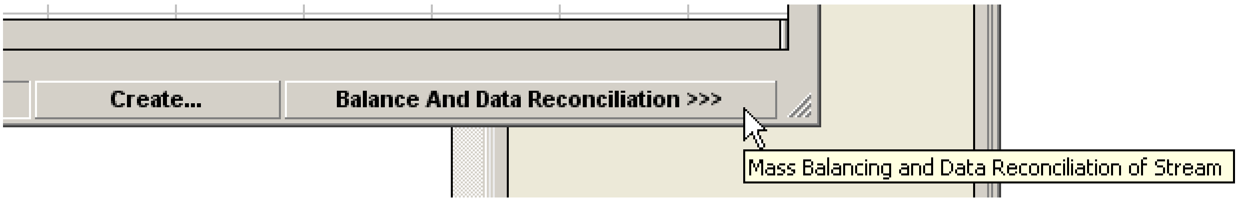


Figure 10. Press "Balance and Data Reconciliation >>>" button.

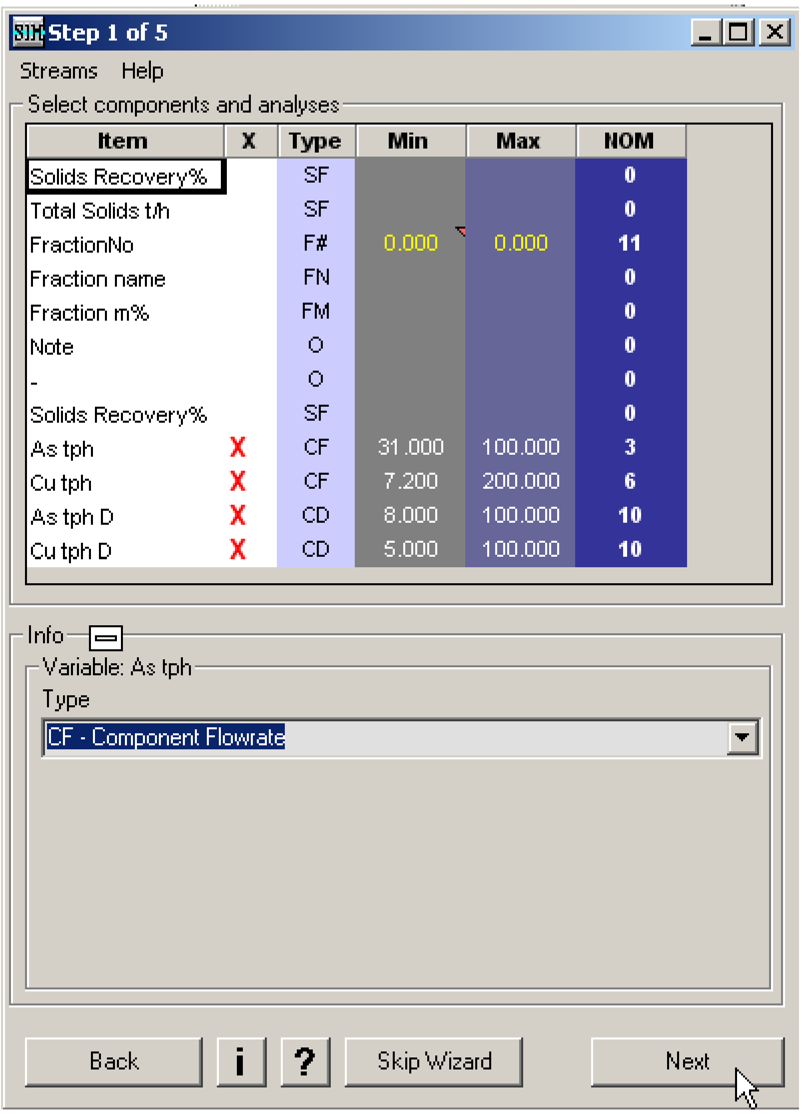


Figure 11. The Mass Balance wizard, step 1.

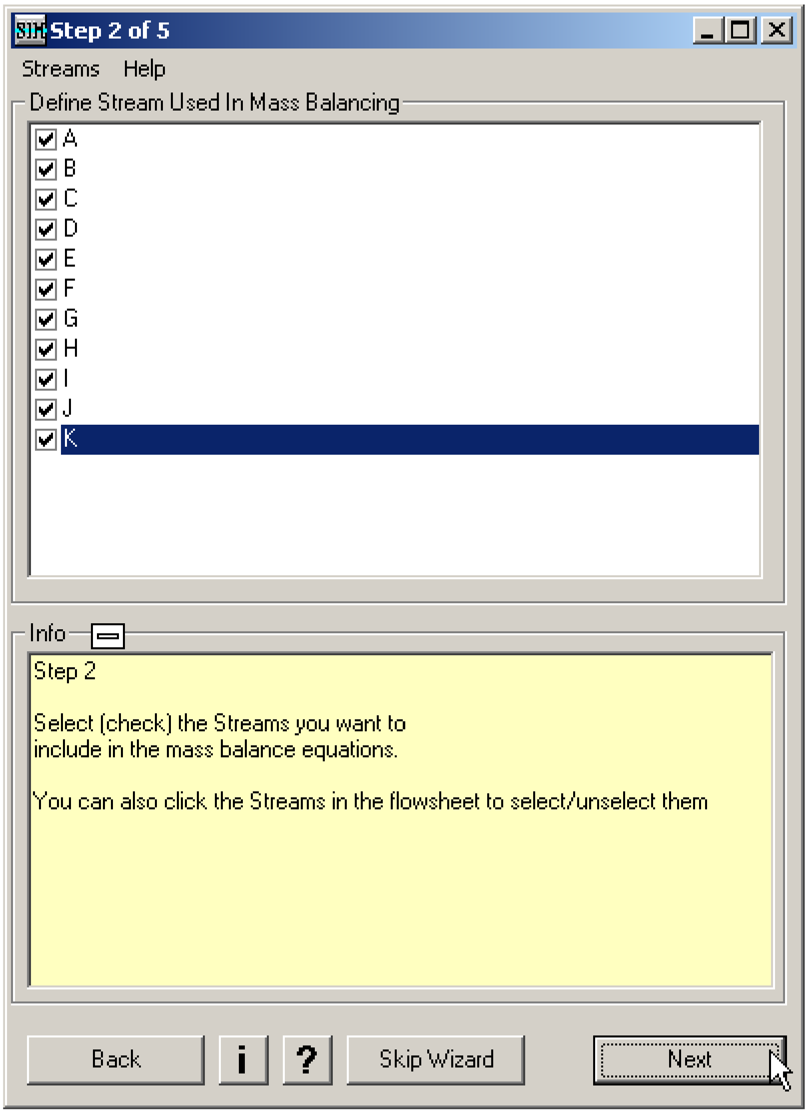


Figure 12. Step 2.

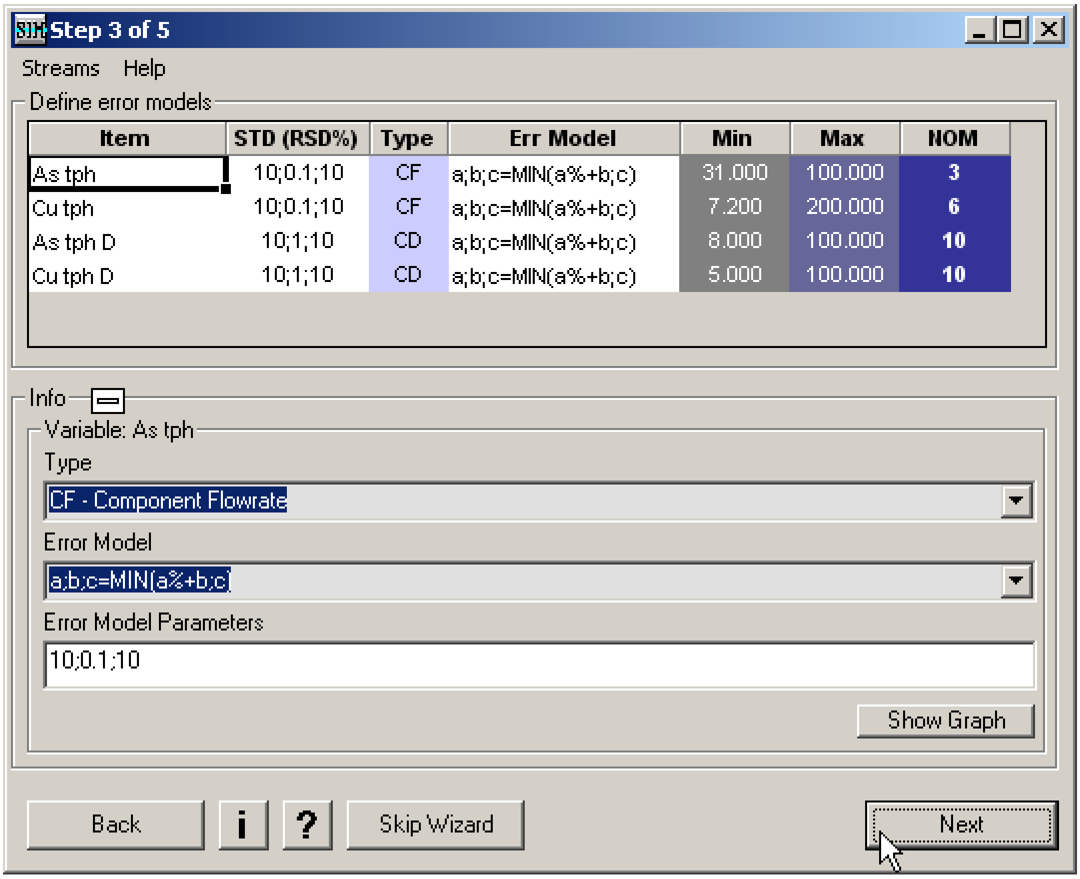


Figure 13. Step 3.

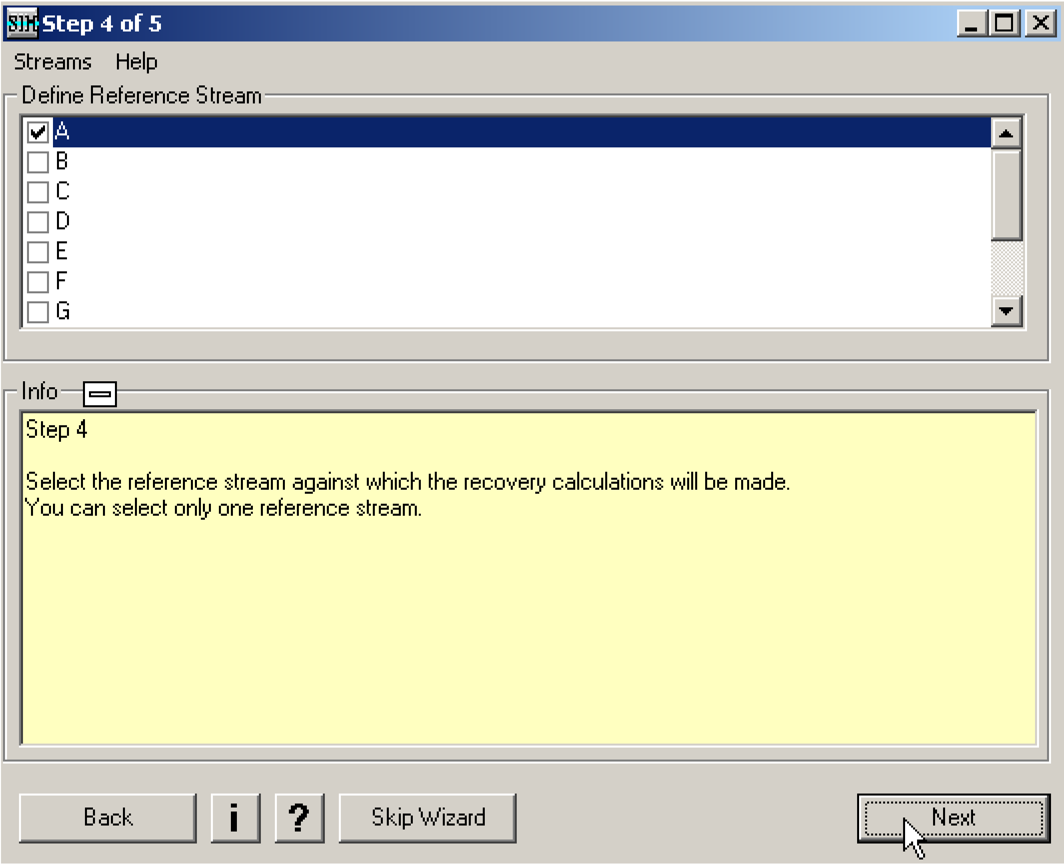


Figure 14. Step 4. Reference stream

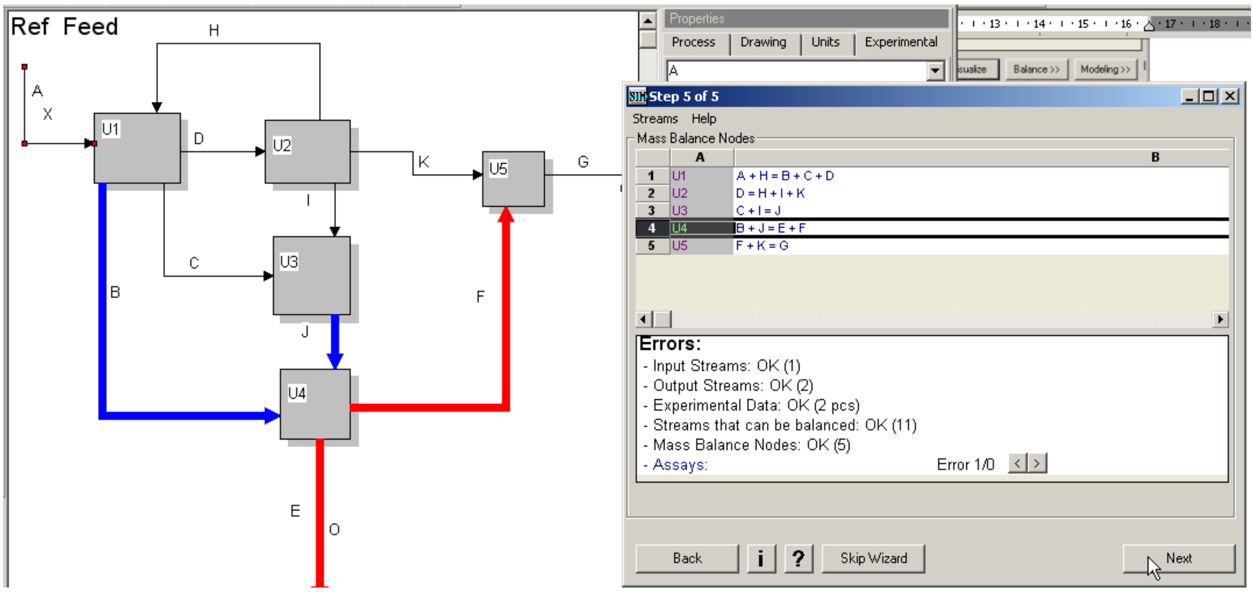


Figure 15. Step 5. Nodes, node 4 is visualized: blue streams are the feed streams of the node, red ones are the output streams. Narrow black streams are not included in the node 4. Number oif errors is zero.

49.2.4. Mass Balancing Window

After the mass balancing wizard you can see the Data Balancing and Reconciliation window (Figure 16). The left part of the window shows Dimension selector and Step **Navigator** (Figure 17) and Data indicator (Figure 18). In the middle you can see the **Data Sheet** (Figure 19). On right hand side you can see the **Balance/Report Options**. To solve the mass balancing problem press 6. Run Balancing or Balance And Reconcile ! button.

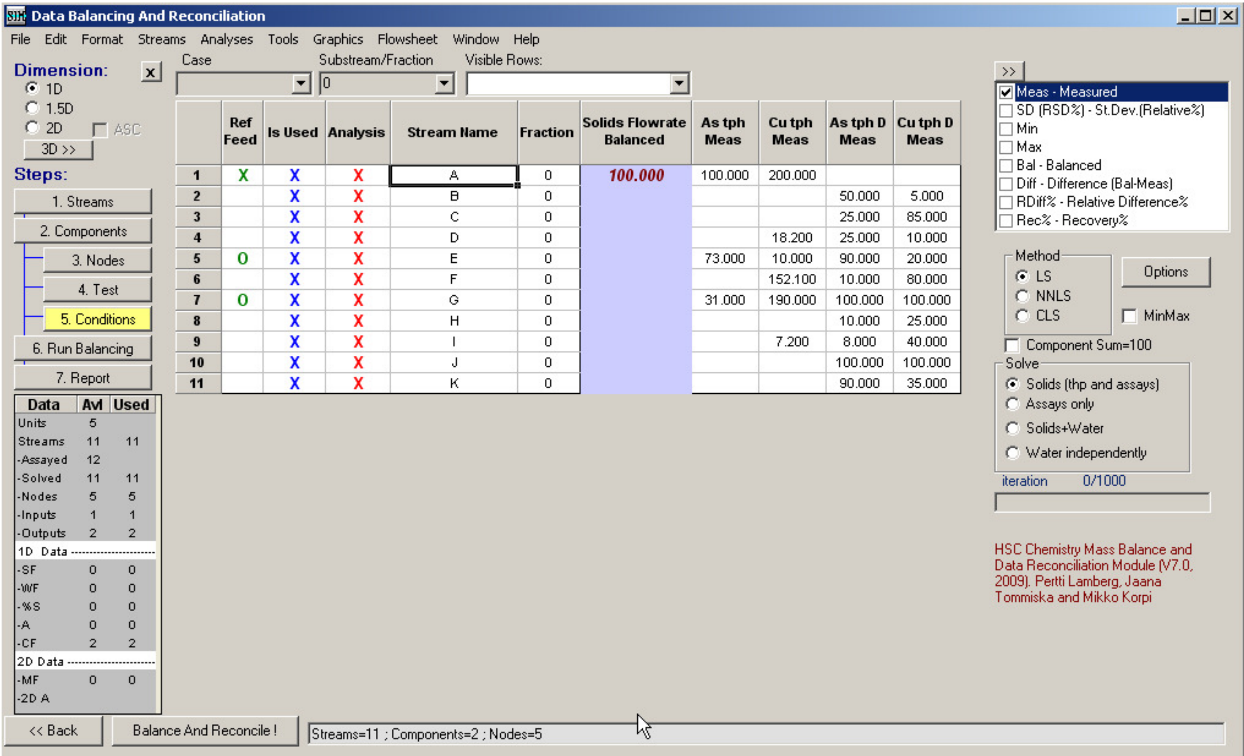


Figure 16. Mass Balancing and Data Reconciliation window.

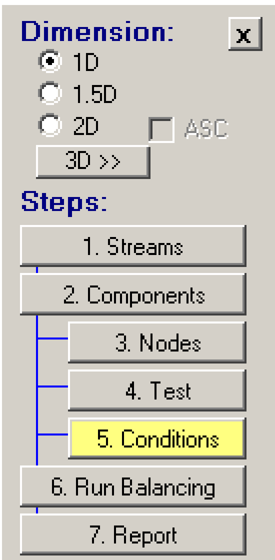


Figure 17. Navigator including dimension selector and step navigator.

Data	Avl	Used
Units	5	
Streams	11	11
-Assayed	12	
-Solved	11	11
-Nodes	5	5
-Inputs	1	1
-Outputs	2	2
1D Data --------------------		
-SF	0	0
-WF	0	0
-%S	0	0
-A	0	0
-CF	2	2
2D Data --------------------		
-MF	0	0
-2D A		

Figure 18. Data indicator.

Case | Substream/Fraction: 0 | Visible Rows:

	Ref Feed	Is Used	Analysis	Stream Name	Fraction	Solids Flowrate Balanced	As tph Meas	Cu tph Meas	As tph D Meas	Cu tph D Meas
1	X	X	X	A	0	100.000	100.000	200.000		
2		X	X	B	0				50.000	5.000
3		X	X	C	0				25.000	85.000
4		X	X	D	0			18.200	25.000	10.000
5	O	X	X	E	0		73.000	10.000	90.000	20.000
6		X	X	F	0			152.100	10.000	80.000
7	O	X	X	G	0		31.000	190.000	100.000	100.000
8		X	X	H	0				10.000	25.000
9		X	X	I	0			7.200	8.000	40.000
10		X	X	J	0				100.000	100.000
11		X	X	K	0				90.000	35.000

Figure 19. Data sheet.

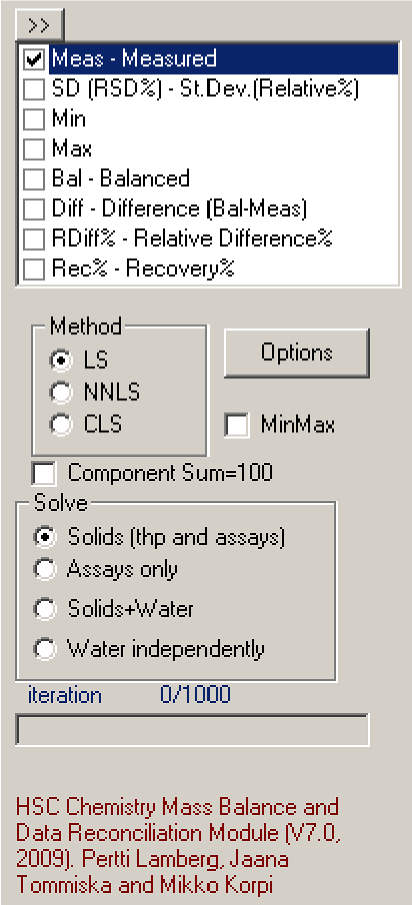


Figure 20. Balance/Report options.

Once you press the press 

or 

button HSC Sim solves the mass balance problem. Balanced (Bal) columns become visible, i.e. now you have visible measured values (white background) and balanced values (grey background). To see more columns check the ones you want to see in the report options / column selector (Figure 22). To visualize the balance in the flowsheet click the column in the data sheet (Figure 23) and see the flowsheet (Figure 24). Use copy/paste to report out for example in MS Word.

Now HSC Sim has adjusted all arsenic tonnages, but we would like to see the feed tonnages, 100 tph, remain unchanged. There are two options for that: 1) set the standard deviation for the stream A / As tph very small, say 0.01 (Figure 25); 2) set the minimum and maximum values to 100 and 100 and select the solution method to CLS (Constrained Least Squares) (Figure 26).

To report result as Stream Tables, Select from the menu “Flowsheet – Create Stream Tables” (Figure 27), select the components (Figure 28) and items (Figure 29). In the next window answer “Yes” to remove the tables with no values (Figure 30). Oranize the tables in the flowsheet in a way that all tables and streams can be seen (Figure 31). Use copy/paste to report out.

Click Report and in the StreamSummary sheet select reported items and press Copy to get the data into the clipboard (Figure 32). Paste into for example MS Excel.

To save the full result select File – Save and give a name for the file (Figure 33).

	Ref Feed	Is Used	Analysis	Stream Name	Fraction	Solids Flowrate Balanced	As tph Meas	As tph Bal	Cu tph Meas	Cu tph Bal	As tph D Meas	As tph D Bal	Cu tph D Meas	Cu tph D Bal
1	X	X	X	A	0	189.516	100.000	102.765	200.000	189.516		0.000		0.000
2		X	X	B	0	2.054		53.930		2.054	50.000	51.296	5.000	1.058
3		X	X	C	0	173.823		25.599		173.823	25.000	24.349	85.000	89.565
4		X	X	D	0	18.197		25.605	18.200	18.197	25.000	24.355	10.000	9.376
5	O	X	X	E	0	10.002	73.000	71.809	10.000	10.002	90.000	88.191	20.000	5.463
6		X	X	F	0	173.076		9.615	152.100	173.076	10.000	11.809	80.000	94.537
7	O	X	X	G	0	179.514	31.000	30.955	190.000	179.514	100.000	100.000	100.000	100.000
8		X	X	H	0	4.558		2.369		4.558	10.000	9.254	25.000	25.050
9		X	X	I	0	7.200		1.896	7.200	7.200	8.000	7.403	40.000	39.567
10		X	X	J	0	181.023		27.495		181.023	100.000	100.000	100.000	100.000
11		X	X	K	0	6.439		21.340		6.439	90.000	83.344	35.000	35.383

Figure 21. Mass Balance solved and data reconciled.

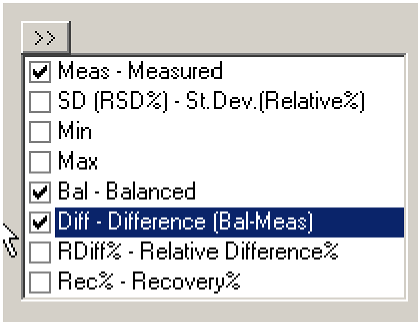


Figure 22. Report options; column selector.

Click column to visualize in the flowsheet

	Ref Feed	Is Used	Analysis	Stream Name	Fraction	Solids Flowrate Balanced	As tph Meas	As tph	As tph Diff	Cu tph Meas	Cu tph Bal
1	X	X	X	A	0	189.516	100.000	102.765	2.76	200.000	189.516
2		X	X	B	0	2.054		53.930			2.054
3		X	X	C	0	173.823		25.599			173.823
4		X	X	D	0	18.197		25.605		18.200	18.197
5	O	X	X	E	0	10.002	73.000	71.809	-1.19	10.000	10.002
6		X	X	F	0	173.076		9.615		152.100	173.076
7	O	X	X	G	0	179.514	31.000	30.955	-0.04	190.000	179.514
8		X	X	H	0	4.558		2.369			4.558
9		X	X	I	0	7.200		1.896		7.200	7.200
10		X	X	J	0	181.023		27.495			181.023
11		X	X	K	0	6.439		21.340			6.439

Figure 23. Clicking As tph to visualize in the flowsheet (see next figure).

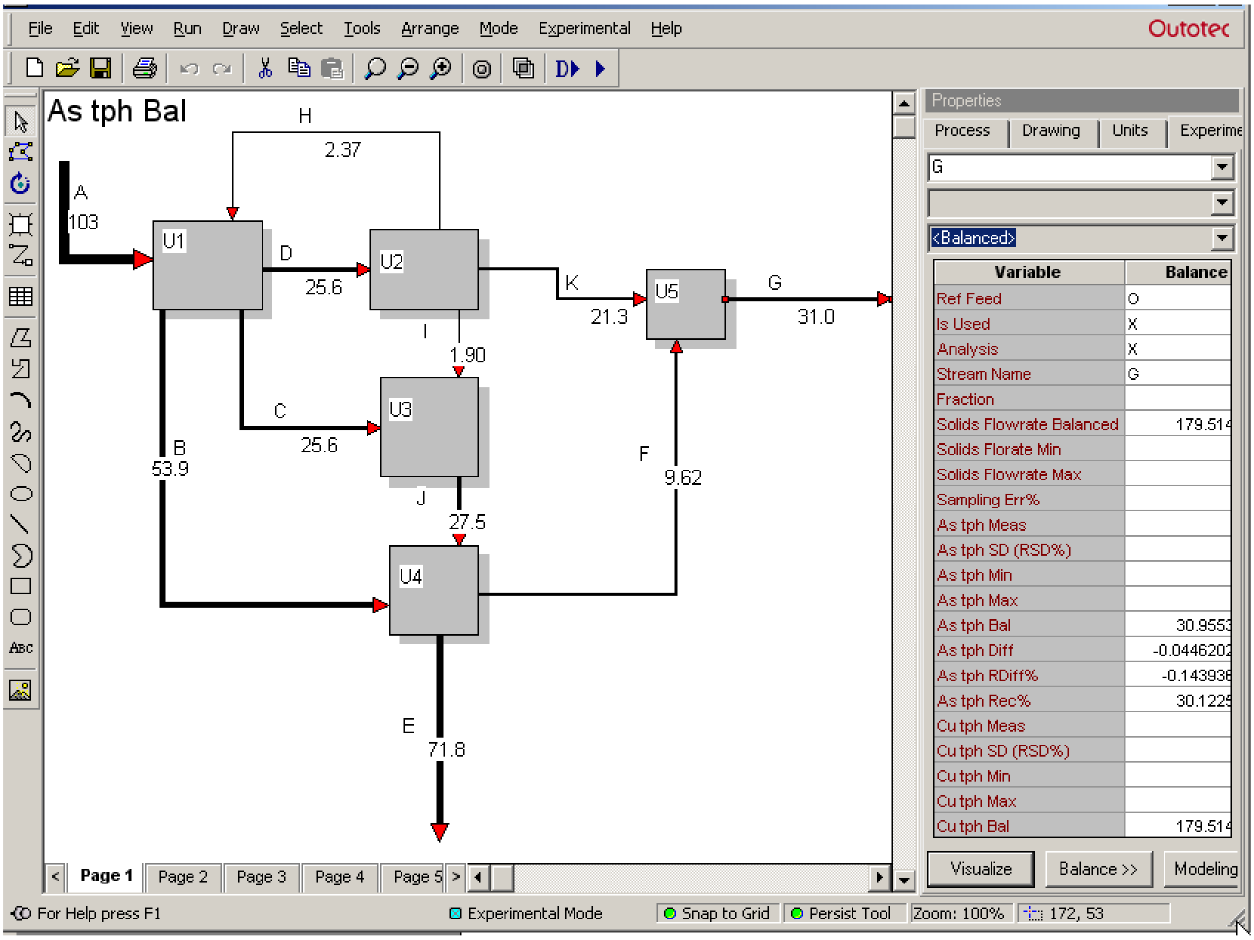


Figure 24. Selected item reported in the flowsheet.

As tph Meas	As tph SD (RSD%)	As tph Bal
100.000	0.001	100.000
	10.000	51.182
	10.000	25.592
	10.000	25.595
73.000	7.400	69.138
	10.000	9.533
31.000	3.200	30.862
	10.000	2.370
	10.000	1.896
	10.000	27.488
	10.000	21.329

Figure 25. As tph for the stream A set to 0.001. Now balanced As tph is practically equal to the measured one.

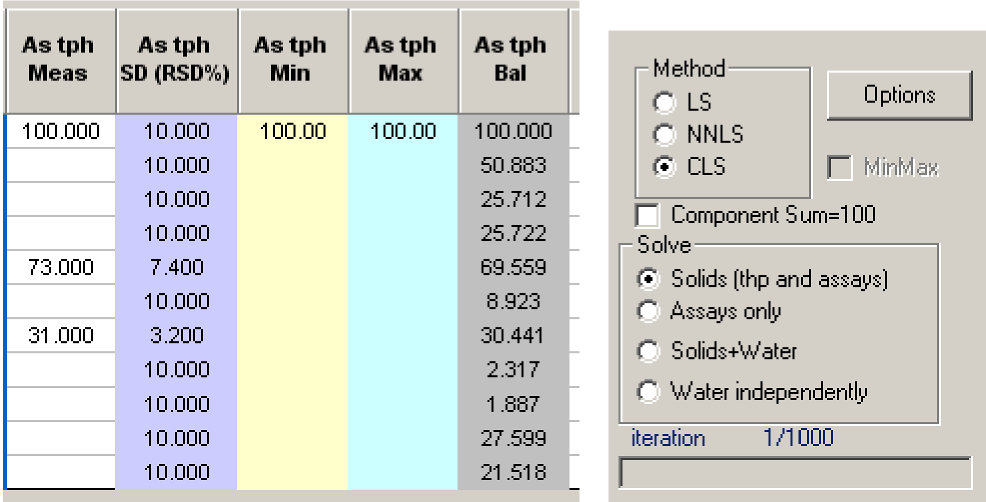


Figure 26. Setting min and max values for As to 100 and 100 and pressing Balance will solve the As flowrate using constraints. Remember to change the solution method to CLS (Constrained Least Squares).

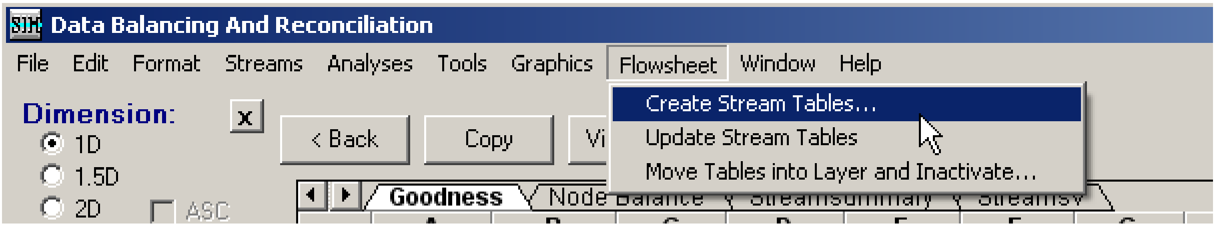


Figure 27. Create Stream Tables.

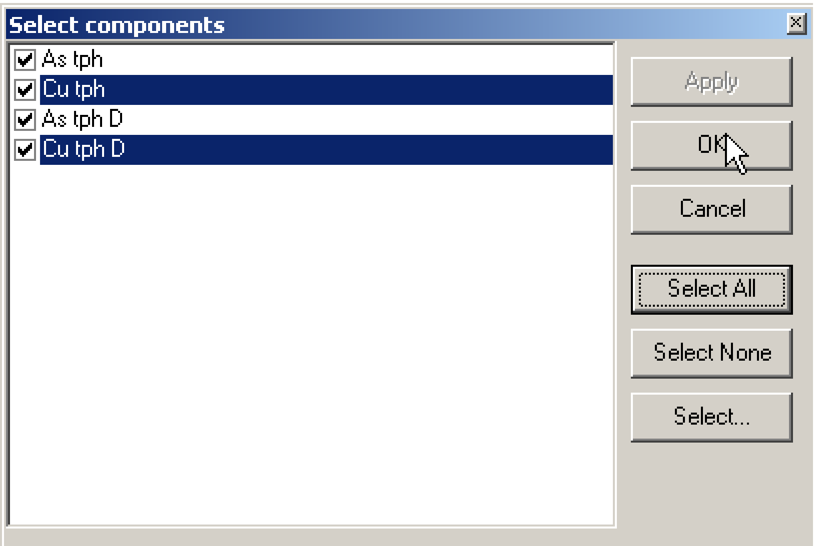


Figure 28. Selecting components to be reported.

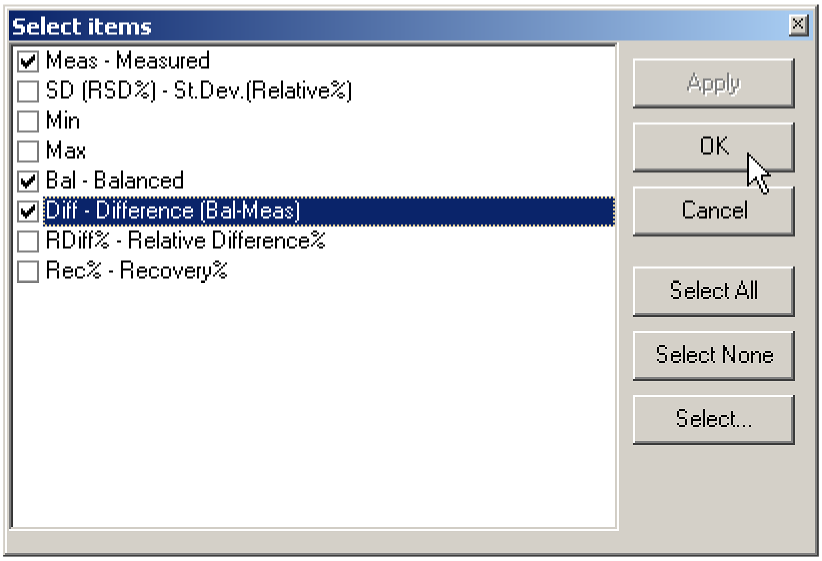


Figure 29. Selecting items.

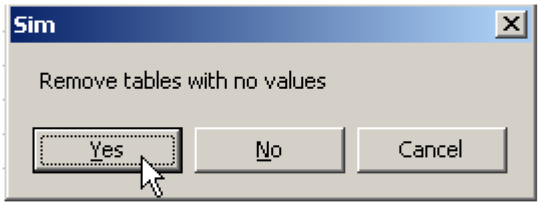


Figure 30. Tables with no values are removed.

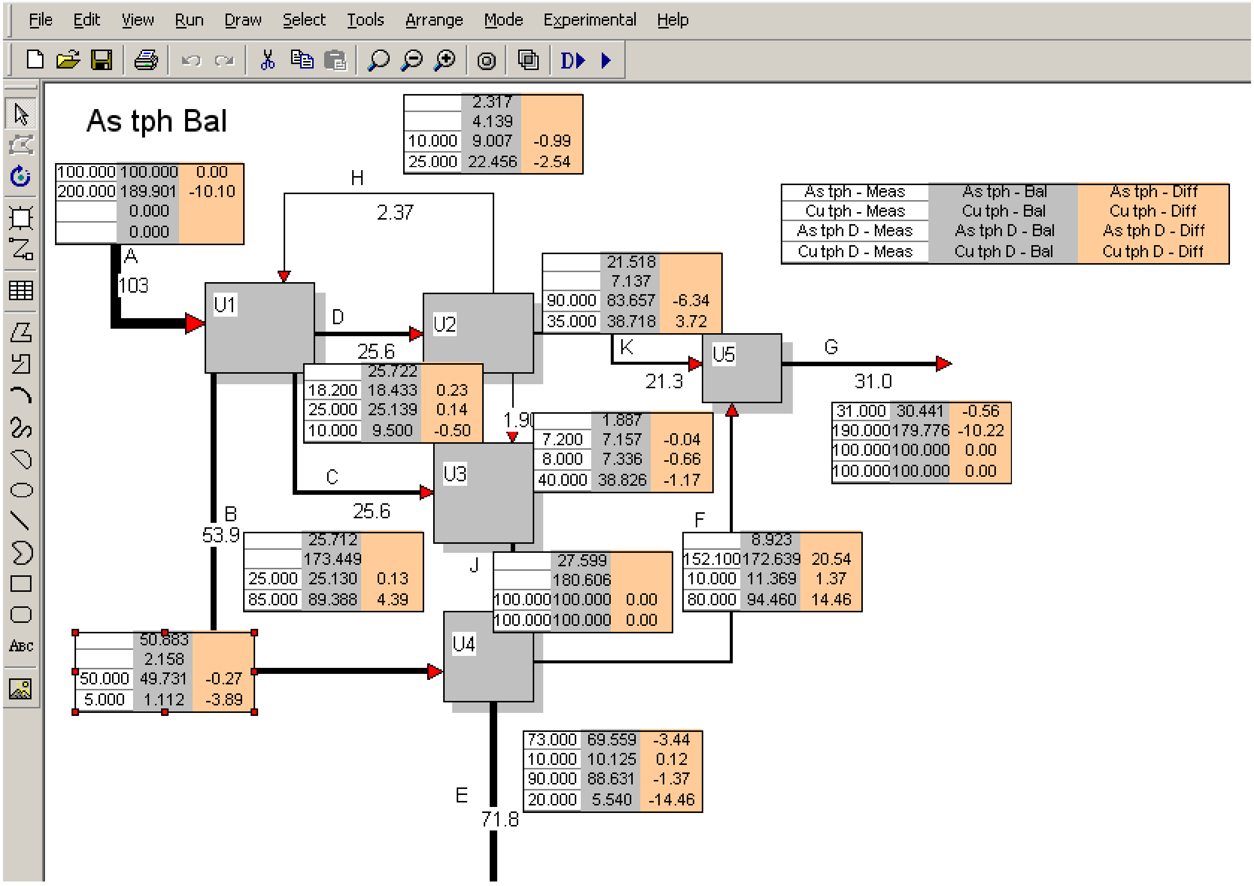


Figure 31. Balance result reported as Stream Tables which are placed on Balance Layer.

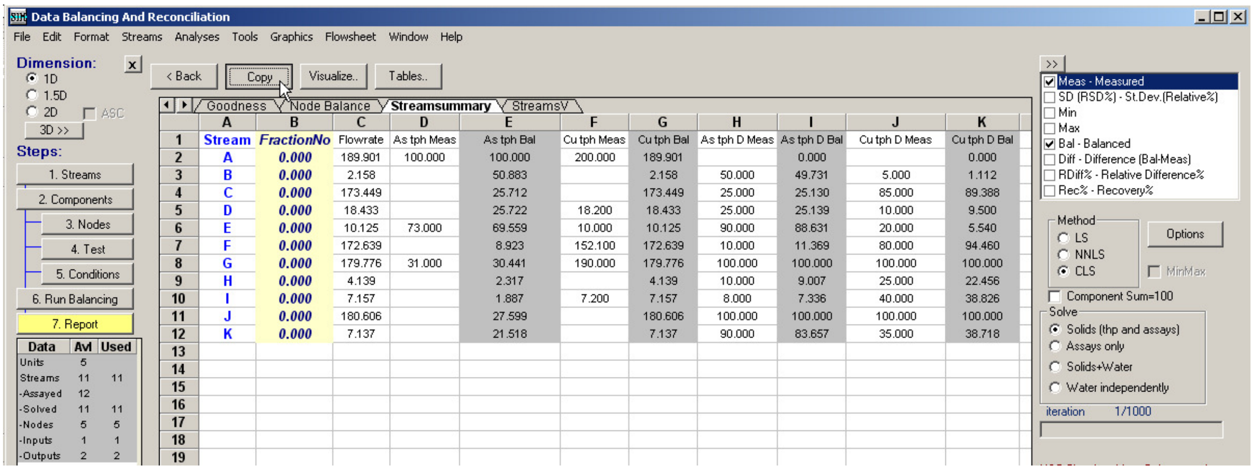


Figure 32. Reporting.

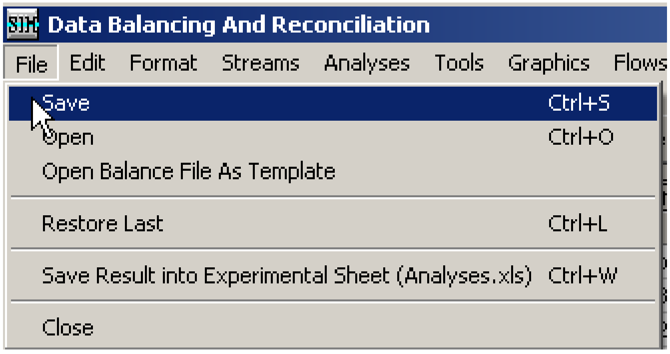


Figure 33. Saving balance file.

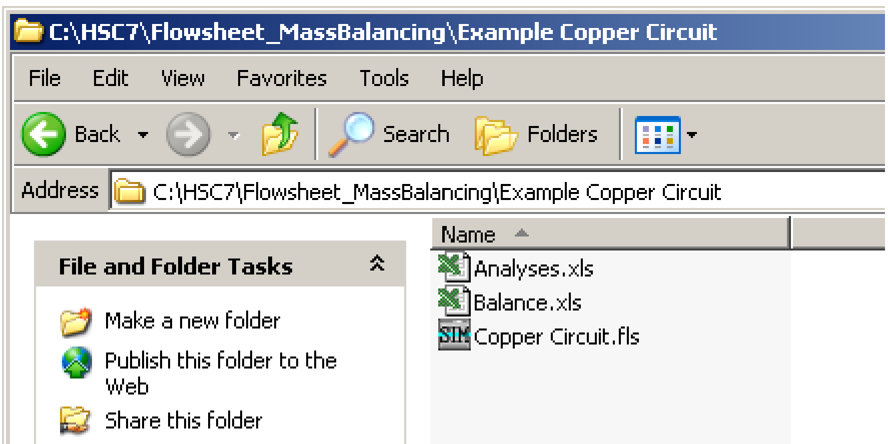
49.3. Example 2 – 1D Chemical Components

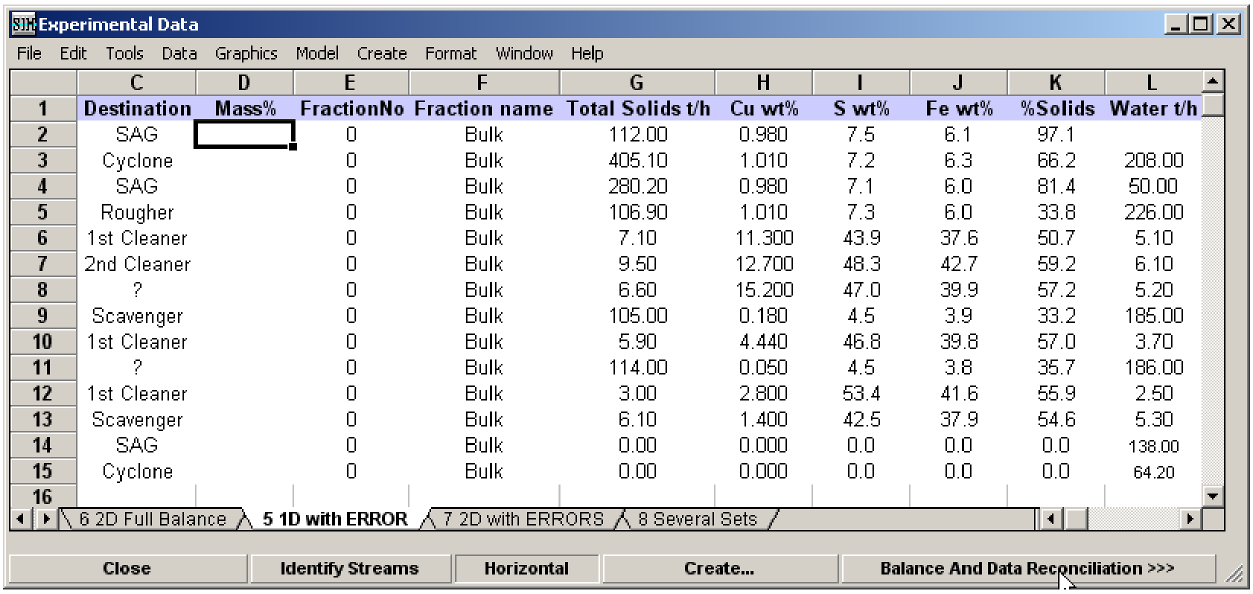
The 1D Chemical Components example can be found in C:\HSC7\Flowsheet_MassBalancing\Example Copper Circuit. The file is Copper Circuit.fls (Figure 33). In the Experimental Data select sheet "5 1D with ERROR" (Figure 34).

In the Mass Balance Wizards keep the default values, or you can even Skip the wizards (Figure 35). In the Data Balancing and Reconciliation press [6. Run Balancing] or [Balance And Reconcile !] button to solve the mass balance.

With the basic options you will find that there are some negative numbers and %Solids and Water have not been solved (Figure 36). To overcome the negative values select Non-Negative Least Squares (NNLS) method. For solving also water and %solids select Solids+water of Water Independently. The former solves all simultaneously the latter solves first solids and then solves %solids and Water using Solids solution as constraints.

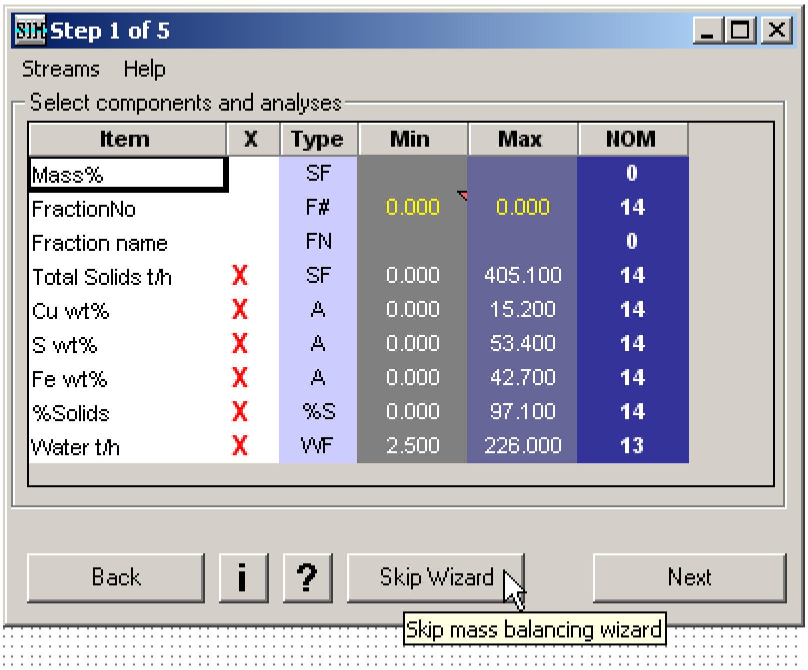
Now mass balance result does not have any negative values and Water and %Solids are also solved. However, the Mill Water has 0.65 t/h solids and ROM has been adjusted to 114 t/h. For the former we set min and max to zero and latter min=max=112 t/h (Figure 39). The solutions is showed in Figure 40.





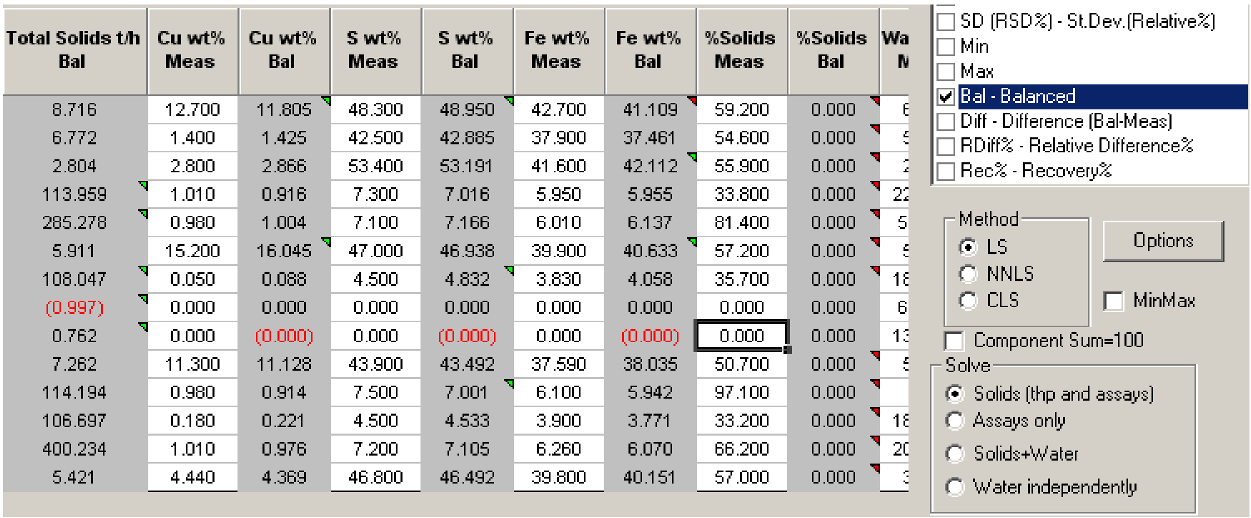
	C	D	E	F	G	H	I	J	K	L
1	Destination	Mass%	FractionNo	Fraction name	Total Solids t/h	Cu wt%	S wt%	Fe wt%	%Solids	Water t/h
2	SAG		0	Bulk	112.00	0.980	7.5	6.1	97.1	
3	Cyclone		0	Bulk	405.10	1.010	7.2	6.3	66.2	208.00
4	SAG		0	Bulk	280.20	0.980	7.1	6.0	81.4	50.00
5	Rougher		0	Bulk	106.90	1.010	7.3	6.0	33.8	226.00
6	1st Cleaner		0	Bulk	7.10	11.300	43.9	37.6	50.7	5.10
7	2nd Cleaner		0	Bulk	9.50	12.700	48.3	42.7	59.2	6.10
8	?		0	Bulk	6.60	15.200	47.0	39.9	57.2	5.20
9	Scavenger		0	Bulk	105.00	0.180	4.5	3.9	33.2	185.00
10	1st Cleaner		0	Bulk	5.90	4.440	46.8	39.8	57.0	3.70
11	?		0	Bulk	114.00	0.050	4.5	3.8	35.7	186.00
12	1st Cleaner		0	Bulk	3.00	2.800	53.4	41.6	55.9	2.50
13	Scavenger		0	Bulk	6.10	1.400	42.5	37.9	54.6	5.30
14	SAG		0	Bulk	0.00	0.000	0.0	0.0	0.0	138.00
15	Cyclone		0	Bulk	0.00	0.000	0.0	0.0	0.0	64.20
16										

Figure 34. Select sheet "5 1D with ERROR".



Item	X	Type	Min	Max	NOM
Mass%		SF			0
FractionNo		F#	0.000	0.000	14
Fraction name		FN			0
Total Solids t/h	X	SF	0.000	405.100	14
Cu wt%	X	A	0.000	15.200	14
S wt%	X	A	0.000	53.400	14
Fe wt%	X	A	0.000	42.700	14
%Solids	X	%S	0.000	97.100	14
Water t/h	X	WF	2.500	226.000	13

Figure 35. Press Skip Wizard, the default values will be used.



Total Solids t/h Bal	Cu wt% Meas	Cu wt% Bal	S wt% Meas	S wt% Bal	Fe wt% Meas	Fe wt% Bal	%Solids Meas	%Solids Bal	Wa N
8.716	12.700	11.805	48.300	48.950	42.700	41.109	59.200	0.000	6
6.772	1.400	1.425	42.500	42.885	37.900	37.461	54.600	0.000	5
2.804	2.800	2.866	53.400	53.191	41.600	42.112	55.900	0.000	2
113.959	1.010	0.916	7.300	7.016	5.950	5.955	33.800	0.000	22
285.278	0.980	1.004	7.100	7.166	6.010	6.137	81.400	0.000	5
5.911	15.200	16.045	47.000	46.938	39.900	40.633	57.200	0.000	5
108.047	0.050	0.088	4.500	4.832	3.830	4.058	35.700	0.000	18
(0.997)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	6
0.762	0.000	(0.000)	0.000	(0.000)	0.000	(0.000)	0.000	0.000	13
7.262	11.300	11.128	43.900	43.492	37.590	38.035	50.700	0.000	5
114.194	0.980	0.914	7.500	7.001	6.100	5.942	97.100	0.000	
106.697	0.180	0.221	4.500	4.533	3.900	3.771	33.200	0.000	18
400.234	1.010	0.976	7.200	7.105	6.260	6.070	66.200	0.000	20
5.421	4.440	4.369	46.800	46.492	39.800	40.151	57.000	0.000	3

Figure 36. Negative results and %Solids Balanced values are zeros.

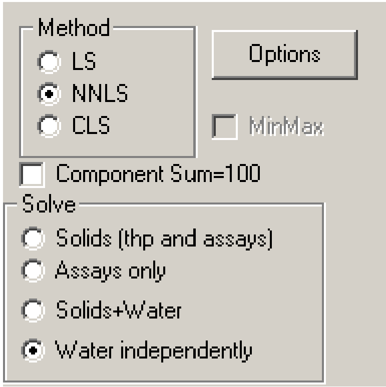


Figure 37. NNLS and Water Independently selected.

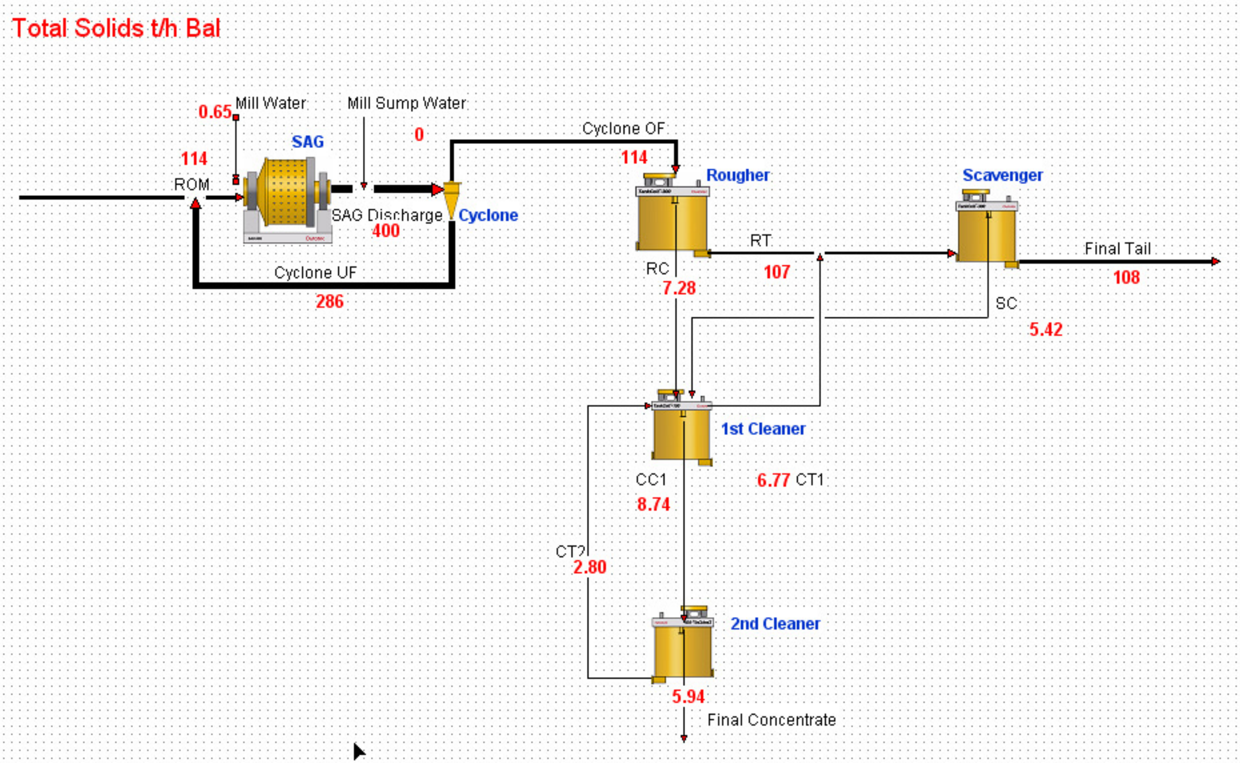


Figure 38. Total Solids flowrate, balanced. Mill Water has 0.65 t/h solids which is not right.

Total Solids t/h Meas	Total Solids t/h Min	Total Solids t/h Max	Total Solids t/h Bal
9.500			8.504
6.100			6.789
3.000			2.869
106.900			112.000
280.200			286.773
6.600			5.635
114.000			106.365
0.000	0.00	0.00	0.000
0.000	0.00	0.00	0.000
7.100			7.020
112.000	112.00	112.00	112.000
105.000			104.980
405.100			398.773
5.900			5.404

Figure 39. Constraints for totals solids t/h.

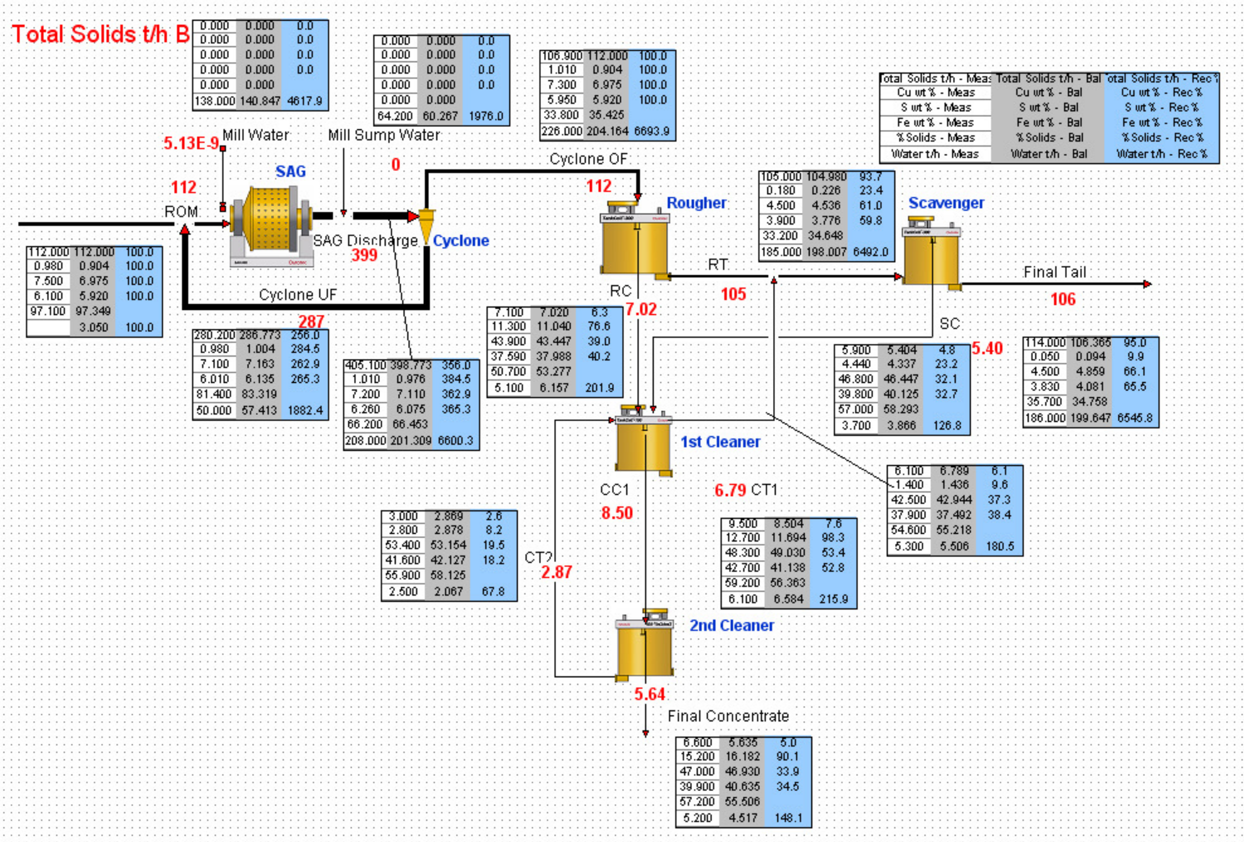


Figure 40. Mass balance of the 1D case.

49.4. Example 3 – 1D Minerals

In 1D minerals we use the vary same example as above, i.e. C:\HSC7\Flowsheet_MassBalancing\Example Copper Circuit. The file is Copper Circuit.fls (Figure 33) and the sheet "5 1D with ERROR" (Figure 34).

When mass balancing with minerals the steps are:

1. Convert elemental grades to mineral grades using HSCGeo
2. Bring the mineral matrix into HSC Sim
3. Solve mineral balance using constraint Sum=100.
4. Bring the solution back to Analyses.
5. Calculate Minerals to Element.

To convert elemental grades to mineral grades select the correct sheet and select Tools – Element To Mineral Conversions – Using HscGeo (Figure 41). In HscGeo press Define >>> to define minerals (Figure 42). Type "chalcopyrite" and select the stoichiometric one and press Add (Figure 43). Continue by adding pyrite and quartz (Figure 44) and press OK to return to Modal Calculation window. Now select Ccp (chalcopyrite) and press > -button to move it to calculation list (Figure 45). Press "Cu" to define that chalcopyrite is calculated from copper (Figure 46). We are confident of copper assays and that chalcopyrite is the only copper mineral and its' composition is stoichiometric. For pyrite we are not so sure. Therefore we will calculate pyrite on the second round using both S and Fe (Figure 47).

The remaining, quartz, is calculated from 100-others, use right mouse button for selecting that option (Figure 48). Press Run to calculate the modal composition (Figure 49). In two samples the mineral sum is higher than 100% (Figure 50). This is due to uncertainties in S and Fe assays which means that our estimate on pyrite is too high. To fix that we use "Normalize" button (Figure 51) define that pyrite is adjusted by selecting "Py", "Total sum is" and "100" and press Calculate (Figure 52). Now the modal calculation is ready. Select from the menu Edit – Copy the Whole Sheet (With Headers) (Figure 53).

Now move back to HSC Sim, activate the "Experimental Data" and select Edit – Paste Special Assays (Figure 54). Mineral analyses are now pasted to HSC Sim (Figure 55). To have the possibility for calculating back to elements go once again back to HscGeo and select Edit – Copy Mineral Matrix (Figure 56), move back to HSC Sim and select Tools – Paste Mineral Matrix (Figure 57). HSC Sim crates a sheet named MinrealMatrix and brings the chemical composition of minerals on that sheet (Figure 58).

Now get back to the sheet "5 1D with ERROR" and press **Balance And Data Reconciliation >>>** -button. In the first Balance Wizard step select "Total Solids Flowrate", "%Solids", "Water", "Ccp", "Py", and "Qtz" (Figure 59). You can skip the other steps (press Skip Wizard).

In the Data Balancing and Reconciliation window set the method to "CLS", check the "Component Sum=100", Solve "Water Independently", set the min and max values for water streams to zero and for ROM to 112. Press solve; the result is shown in Figure 61. For graphical presentation select Graphics – Assays Stacked Bar (Figure 62, Figure 63).

To calculate back to elements result has to be moved back to Experimental Data; use "File – Save Result into Experimental Sheet (Analyses.xls)" (Figure 64). Give name for the balance sheet (Figure 65) and complete the balance by selecting "Tools – Calculate Minerals To Elements" (Figure 66). Now the balance is ready. In the final mineral and elemental balance minerals sum up to 100% and elemental balance is fully compatible mineral balance and the Mineral Matrix (Figure 67).

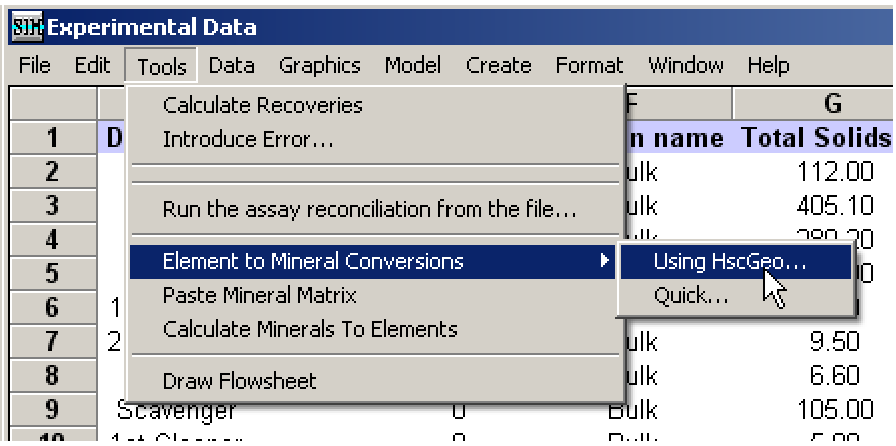


Figure 41. Element to Mineral Conversions, starting HscGeo.

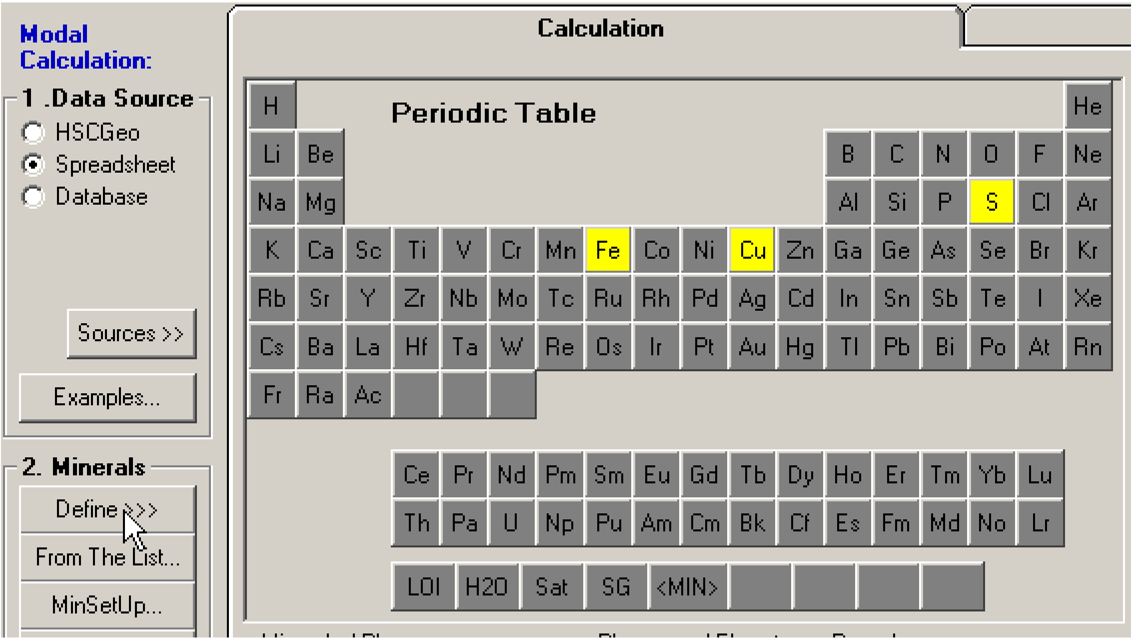


Figure 42. In HscGeo press Define >>> to define minerals.

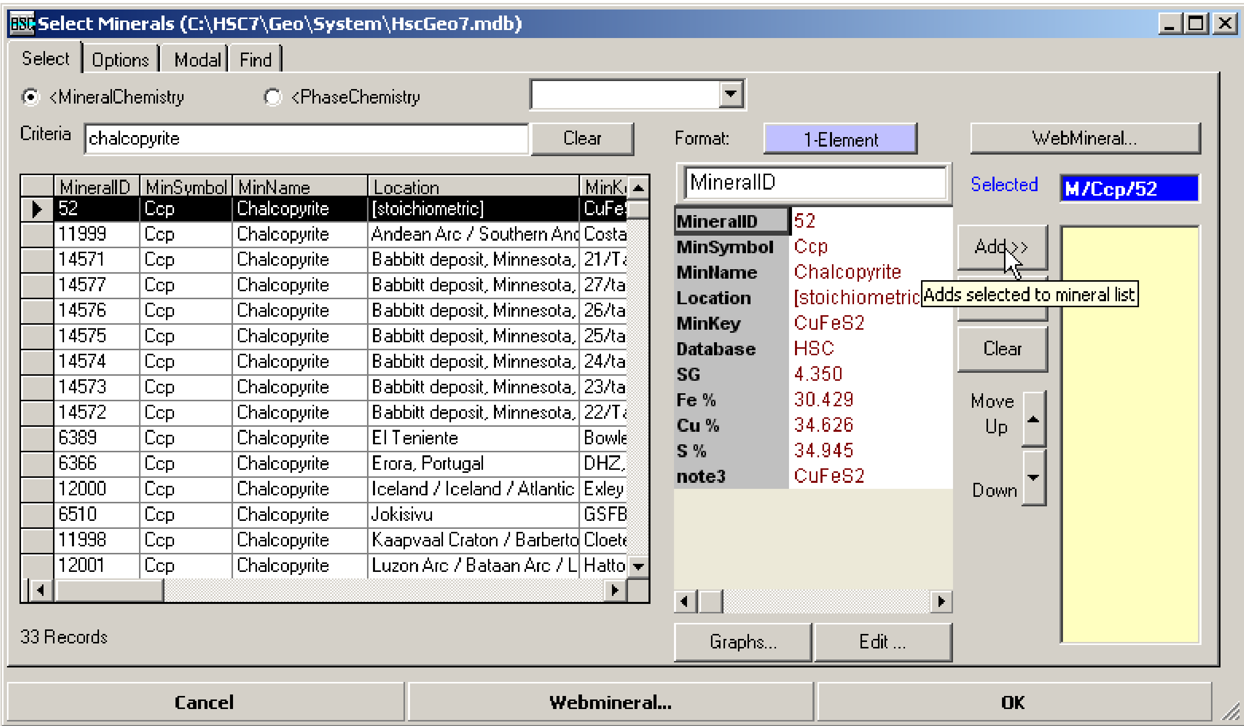


Figure 43. Adding chalcopyrite.

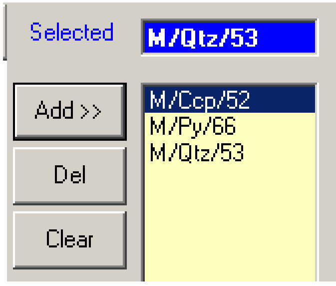


Figure 44. Chalcopyrite, pyrite and quartz added.

Figure 45. Moving Ccp (chalcopyrite) to calculation list.

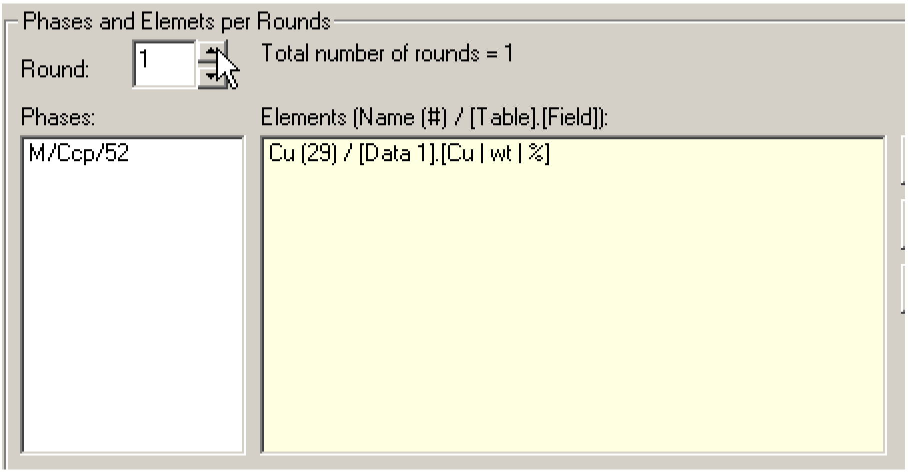


Figure 46. Chalcopyrite –Cu selected for the first round, pressing UP-button to move to the second round.

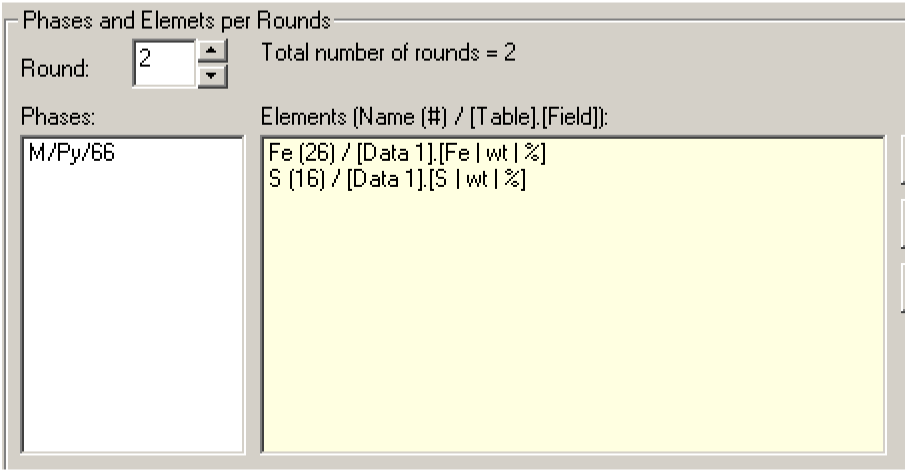


Figure 47. Second round: pyrite using both Fe and S.

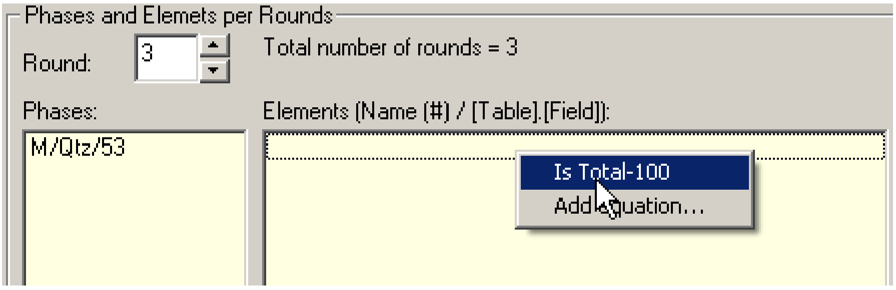
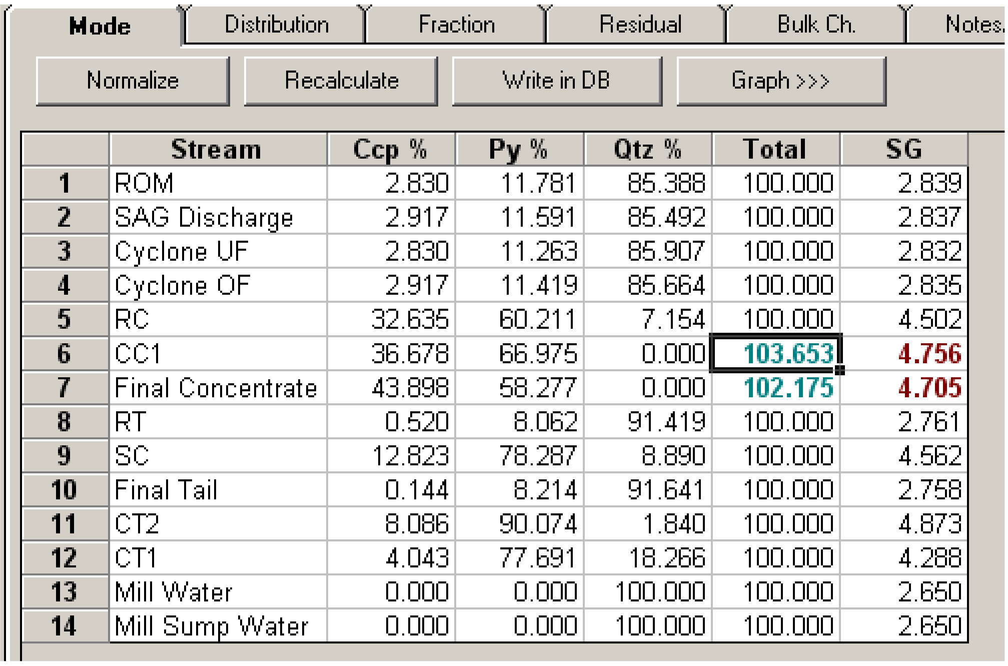


Figure 48. Quartz is calculated on third round using "Is Total-100". Use right mouse to select the option.

Figure 49. Press Calculate to run the modal calculation.



	Stream	Ccp %	Py %	Qtz %	Total	SG
1	ROM	2.830	11.781	85.388	100.000	2.839
2	SAG Discharge	2.917	11.591	85.492	100.000	2.837
3	Cyclone UF	2.830	11.263	85.907	100.000	2.832
4	Cyclone OF	2.917	11.419	85.664	100.000	2.835
5	RC	32.635	60.211	7.154	100.000	4.502
6	CC1	36.678	66.975	0.000	103.653	4.756
7	Final Concentrate	43.898	58.277	0.000	102.175	4.705
8	RT	0.520	8.062	91.419	100.000	2.761
9	SC	12.823	78.287	8.890	100.000	4.562
10	Final Tail	0.144	8.214	91.641	100.000	2.758
11	CT2	8.086	90.074	1.840	100.000	4.873
12	CT1	4.043	77.691	18.266	100.000	4.288
13	Mill Water	0.000	0.000	100.000	100.000	2.650
14	Mill Sump Water	0.000	0.000	100.000	100.000	2.650

Figure 50. In two samples the total is higher than 100%.

Figure 51. To adjust pyrite select "Normalize" and…

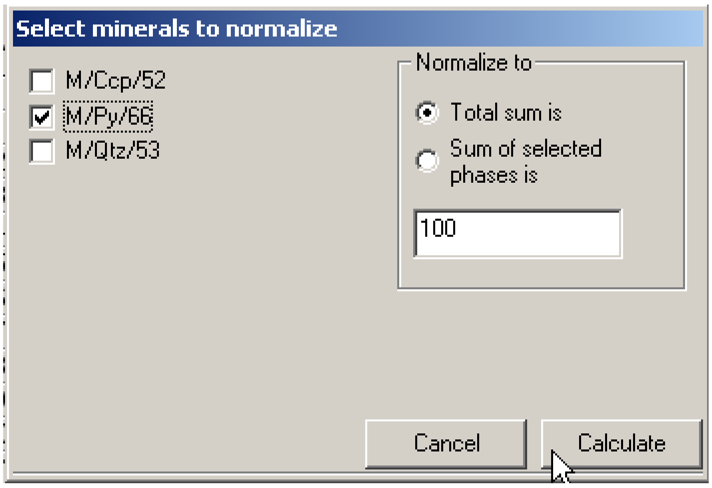


Figure 52. …select "Py" and "Total sum is", "100" and press Calculate.

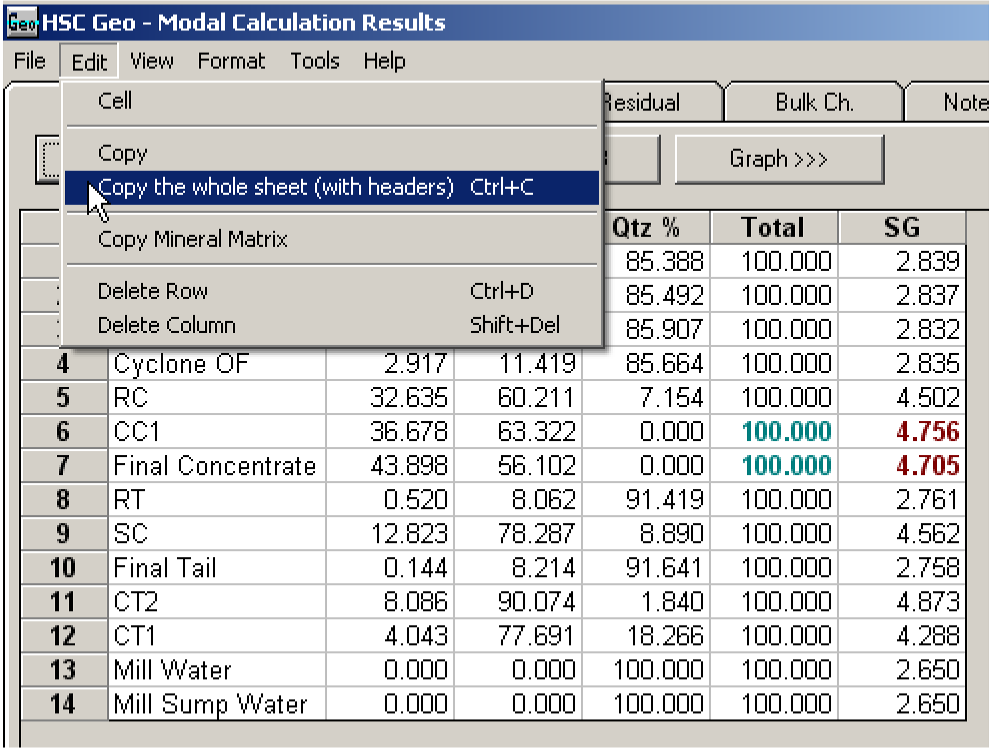


Figure 53. Copy the modal composition to the clipboard.

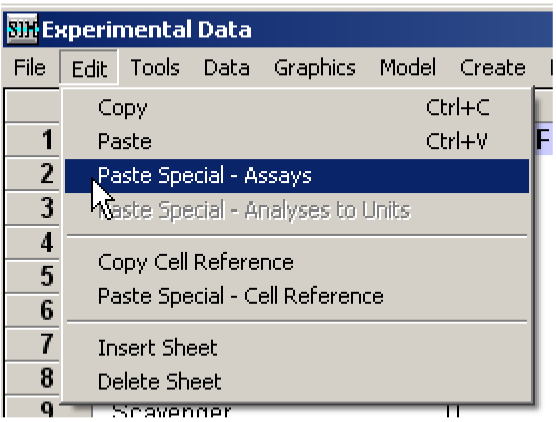
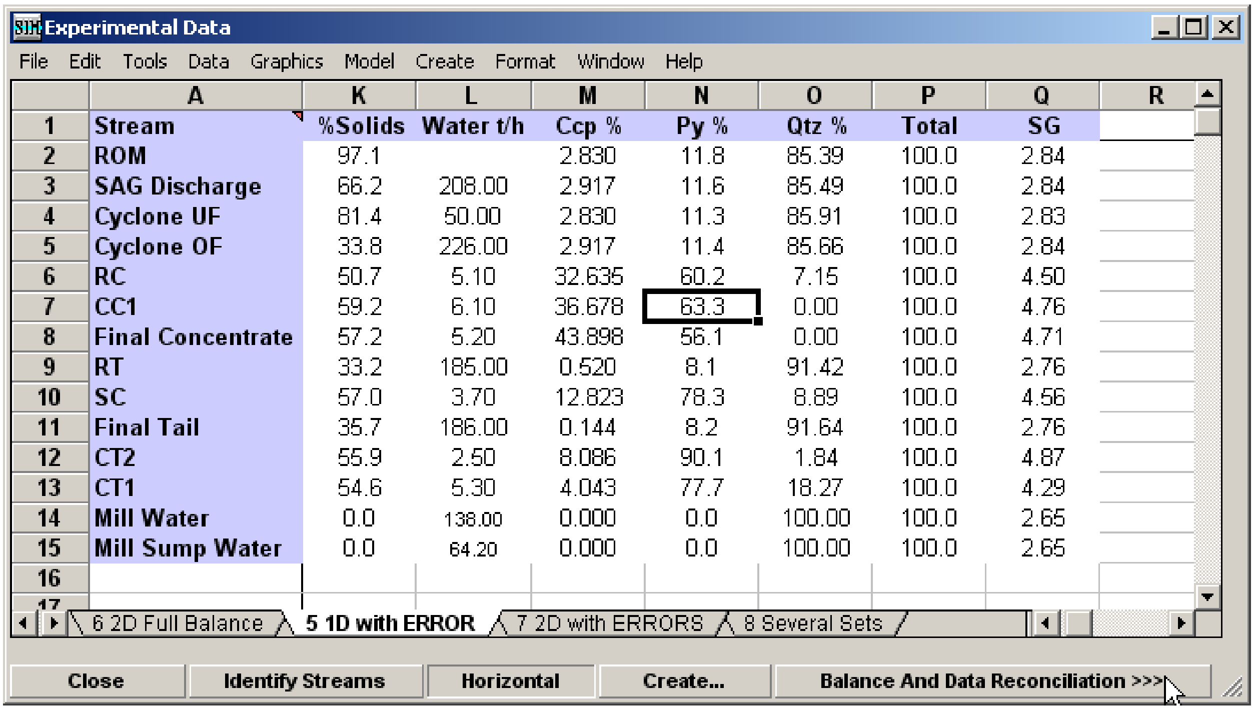


Figure 54. In HSC Sim select Edit – Paste Special – Assays.



	A	K	L	M	N	O	P	Q	R
1	Stream	%Solids	Water t/h	Ccp %	Py %	Qtz %	Total	SG	
2	ROM	97.1		2.830	11.8	85.39	100.0	2.84	
3	SAG Discharge	66.2	208.00	2.917	11.6	85.49	100.0	2.84	
4	Cyclone UF	81.4	50.00	2.830	11.3	85.91	100.0	2.83	
5	Cyclone OF	33.8	226.00	2.917	11.4	85.66	100.0	2.84	
6	RC	50.7	5.10	32.635	60.2	7.15	100.0	4.50	
7	CC1	59.2	6.10	36.678	63.3	0.00	100.0	4.76	
8	Final Concentrate	57.2	5.20	43.898	56.1	0.00	100.0	4.71	
9	RT	33.2	185.00	0.520	8.1	91.42	100.0	2.76	
10	SC	57.0	3.70	12.823	78.3	8.89	100.0	4.56	
11	Final Tail	35.7	186.00	0.144	8.2	91.64	100.0	2.76	
12	CT2	55.9	2.50	8.086	90.1	1.84	100.0	4.87	
13	CT1	54.6	5.30	4.043	77.7	18.27	100.0	4.29	
14	Mill Water	0.0	138.00	0.000	0.0	100.00	100.0	2.65	
15	Mill Sump Water	0.0	64.20	0.000	0.0	100.00	100.0	2.65	
16									

Figure 55. Mineral analyses are brought to HSC Sim (use Format Auto to set autoformat and Window Freeze Panes to fix the top row and left column).

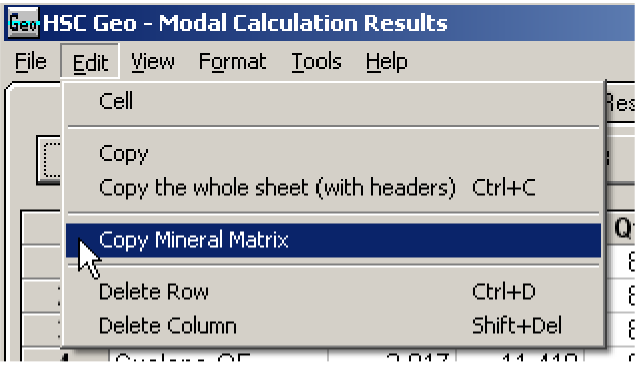


Figure 56. In HscGeo select Edit – Copy Mineral Matrix…

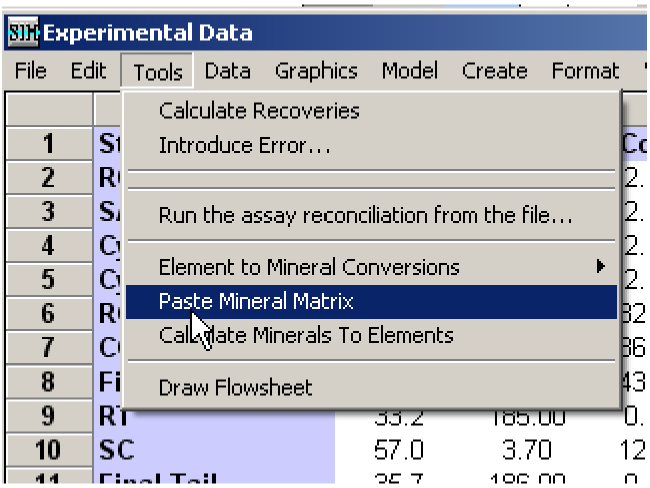


Figure 57. Paste Mineral Matrix to HSC Sim; select Tools – Paste Mineral Matrix.

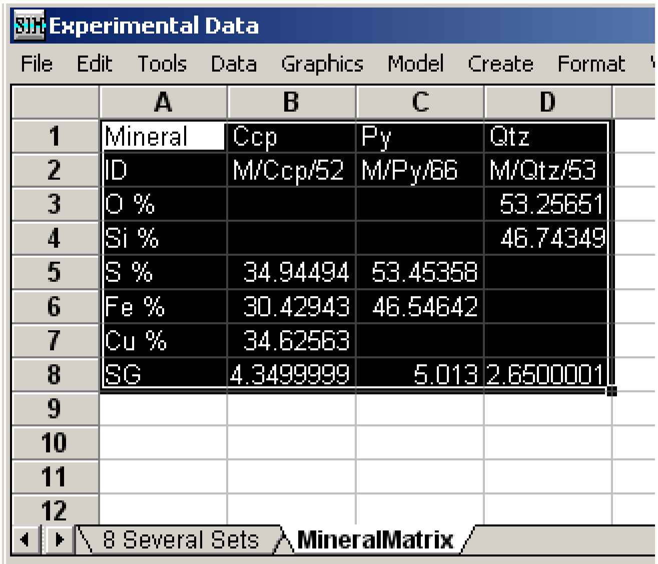


Figure 58. In HSC Sim Mineral Matrix is brought to a sheet MineralMatrix.

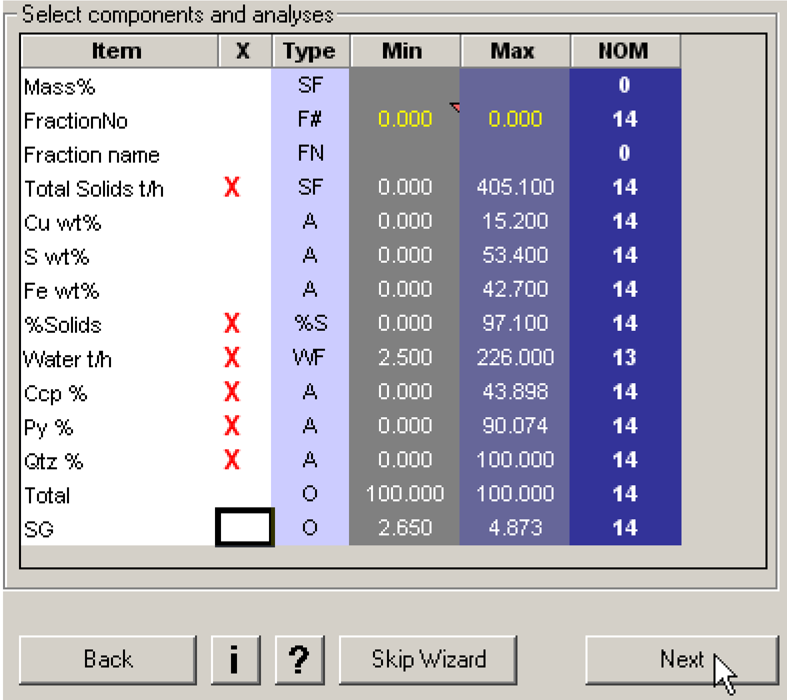


Figure 59. Select flowrates and minerals.

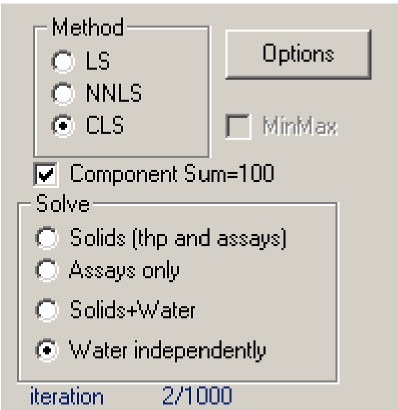


Figure 60. Calculation conditions.

Stream Name	Solids Flowrate Balanced	Total Solids t/h Bal	%Solids Bal	Water t/h Bal	Ccp % Bal	Py % Bal	Qtz % Bal
CC1	8.558	8.558	56.464	6.599	36.524	63.154	0.323
CT1	5.989	5.989	53.690	5.166	4.034	78.170	17.796
CT2	1.711	1.711	51.875	1.588	8.198	90.188	1.614
Cyclone OF	112.000	112.000	35.401	204.372	2.816	11.538	85.646
Cyclone UF	286.687	286.687	83.325	57.371	2.872	11.382	85.746
Final Concentrate	6.847	6.847	57.741	5.011	43.603	56.397	0.000
Final Tail	105.153	105.153	34.531	199.361	0.160	8.617	91.222
Mill Sump Water	0.000	0.000	0.000	60.376	0.000	0.000	100.000
Mill Water	0.000	0.000	0.000	140.913	0.000	0.000	100.000
RC	7.948	7.948	54.984	6.507	32.707	59.584	7.709
ROM	112.000	112.000	97.321	3.083	2.816	11.538	85.646
RT	104.052	104.052	34.464	197.866	0.533	7.868	91.599
SAG Discharge	398.687	398.687	66.442	201.367	2.856	11.426	85.718
SC	4.888	4.888	57.117	3.670	12.839	77.892	9.270

Figure 61. Balanced mineral grades and flowrates.

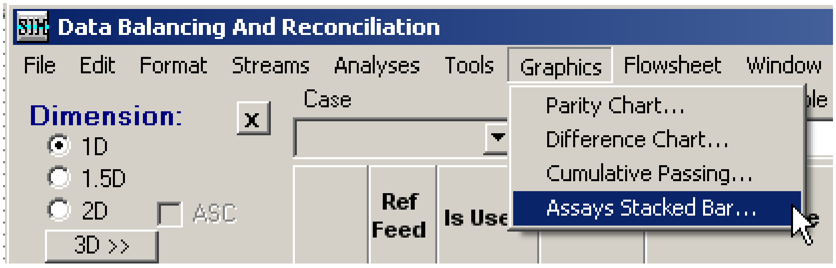


Figure 62. For bar chart select Graphics – Assays Stacked Bar....

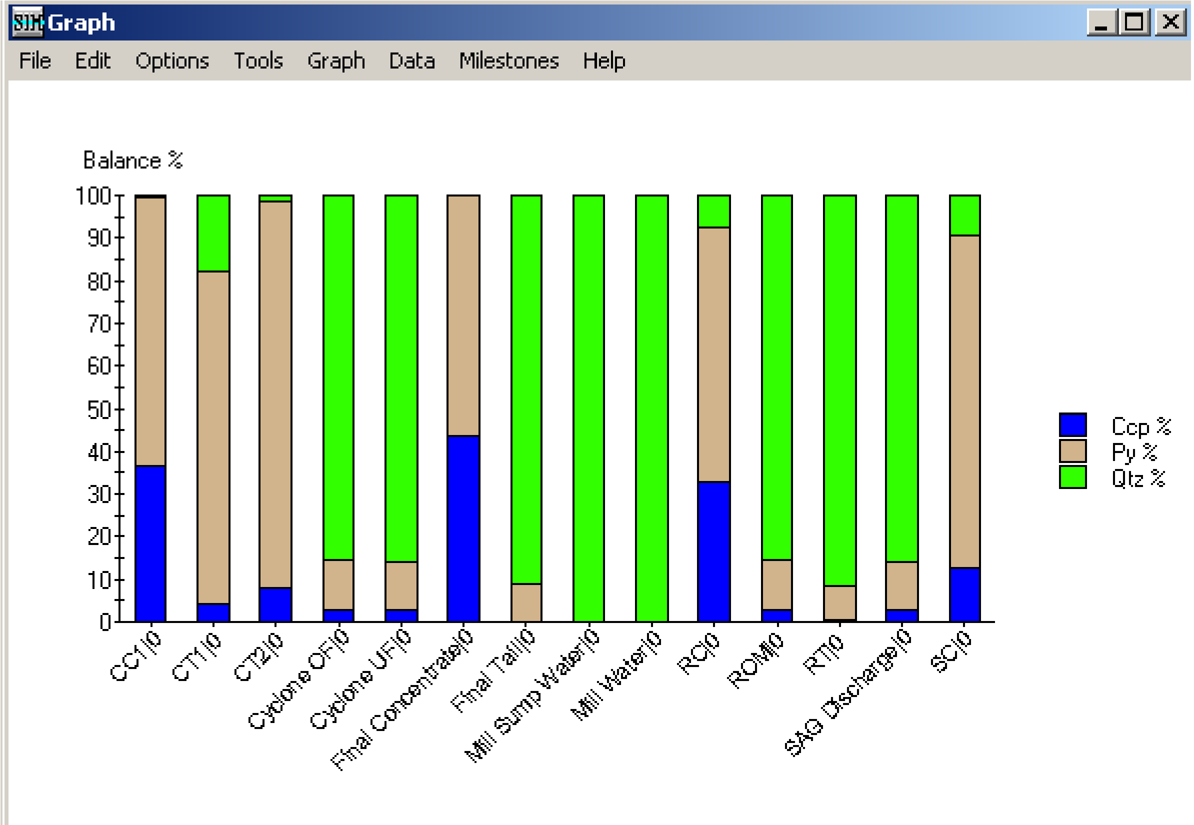


Figure 63. In the Graph window you can see the balanced modal composition.

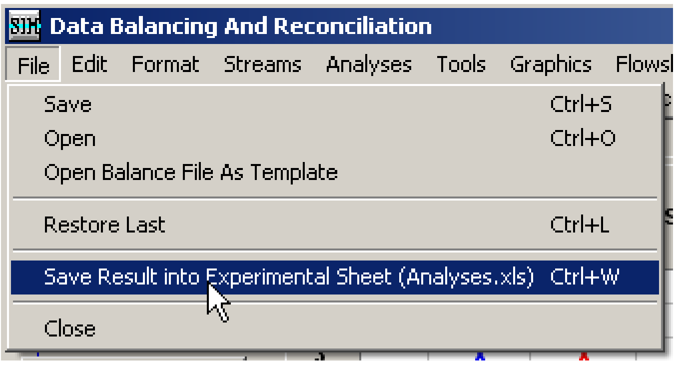


Figure 64. Save balanced result back into Experimental Data by selecting File – Save Result into Experimental Sheet (Analyses.xls).

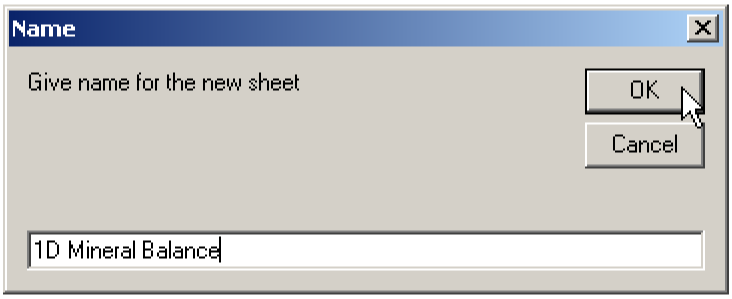


Figure 65. Give name for the balance sheet.

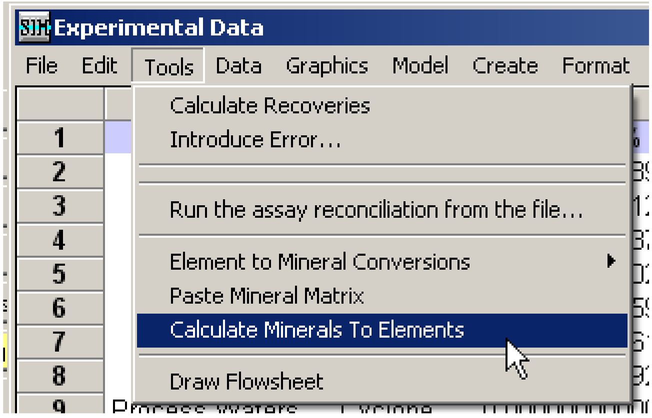


Figure 66. Complete the balance by selecting Tools – Calculate Minerals To Elements.

	A	H	I	J	K	L	M	N	O	P	Q	R	S	T
1	Stream	Water t/h	Ccp %	Py %	Qtz %	O %	Si %	S %	Fe %	Cu %	Ccp Rec%	Py Rec%	Qtz Rec%	O Rec%
2	CC1	6.60	36.524	63.15	0.32	0.172	0.151	46.52	40.51	12.65	99.10	41.82	0.03	0.03
3	CT1	5.17	4.034	78.17	17.80	9.477	8.318	43.19	37.61	1.40	7.66	36.23	1.11	1.11
4	CT2	1.59	8.198	90.19	1.61	0.860	0.754	51.07	44.47	2.84	4.45	11.94	0.03	0.03
5	Cyclone OF	204.37	2.816	11.54	85.65	45.612	40.034	7.15	6.23	0.98	100.00	100.00	100.00	100.00
6	Cyclone UF	57.37	2.872	11.38	85.75	45.665	40.080	7.09	6.17	0.99	261.07	252.51	256.27	256.27
7	Final Concentrate	5.01	43.603	56.40	0.00	0.000	0.000	45.38	39.52	15.10	94.65	29.88	0.00	0.00
8	Final Tail	199.36	0.160	8.62	91.22	48.582	42.641	4.66	4.06	0.06	5.35	70.12	100.00	100.00
9	Mill Sump Water	60.38	0.000	0.00	100.00	53.257	46.743	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	Mill Water	140.91	0.000	0.00	100.00	53.257	46.743	0.00	0.00	0.00	0.00	0.00	0.00	0.00
11	RC	6.51	32.707	59.58	7.71	4.105	3.603	43.28	37.69	11.33	82.42	36.65	0.64	0.64
12	ROM	3.08	2.816	11.54	85.65	45.612	40.034	7.15	6.23	0.98	100.00	100.00	100.00	100.00
13	RT	197.87	0.533	7.87	91.60	48.782	42.816	4.39	3.82	0.18	17.58	63.35	99.36	99.36
14	SAG Discharge	201.37	2.856	11.43	85.72	45.650	40.067	7.11	6.19	0.99	361.07	352.51	356.27	356.27
15	SC	3.67	12.839	77.89	9.27	4.937	4.333	46.12	40.16	4.45	19.90	29.46	0.47	0.47
16														

Figure 67. Final mineral and elemental balance; minerals sum up to 100% and elemental balance is fully compatible mineral balance and the Mineral Matrix.

49.5. Example 4 – 1.5D Mass Balancing

In 1.5D mass balance example we use the vary same example as above, i.e. C:\HSC7\Flowsheet_MassBalancing\Example Copper Circuit. The file is Copper Circuit.fls (Figure 33) and the sheet "3 Grinding Survey (Figure 68). This example demonstrates:

- Vertical data in Experimental Data
- Particle Size distribution balancing
- Drawing includes the whole flowsheet but mass balance is only for part of the circuit.

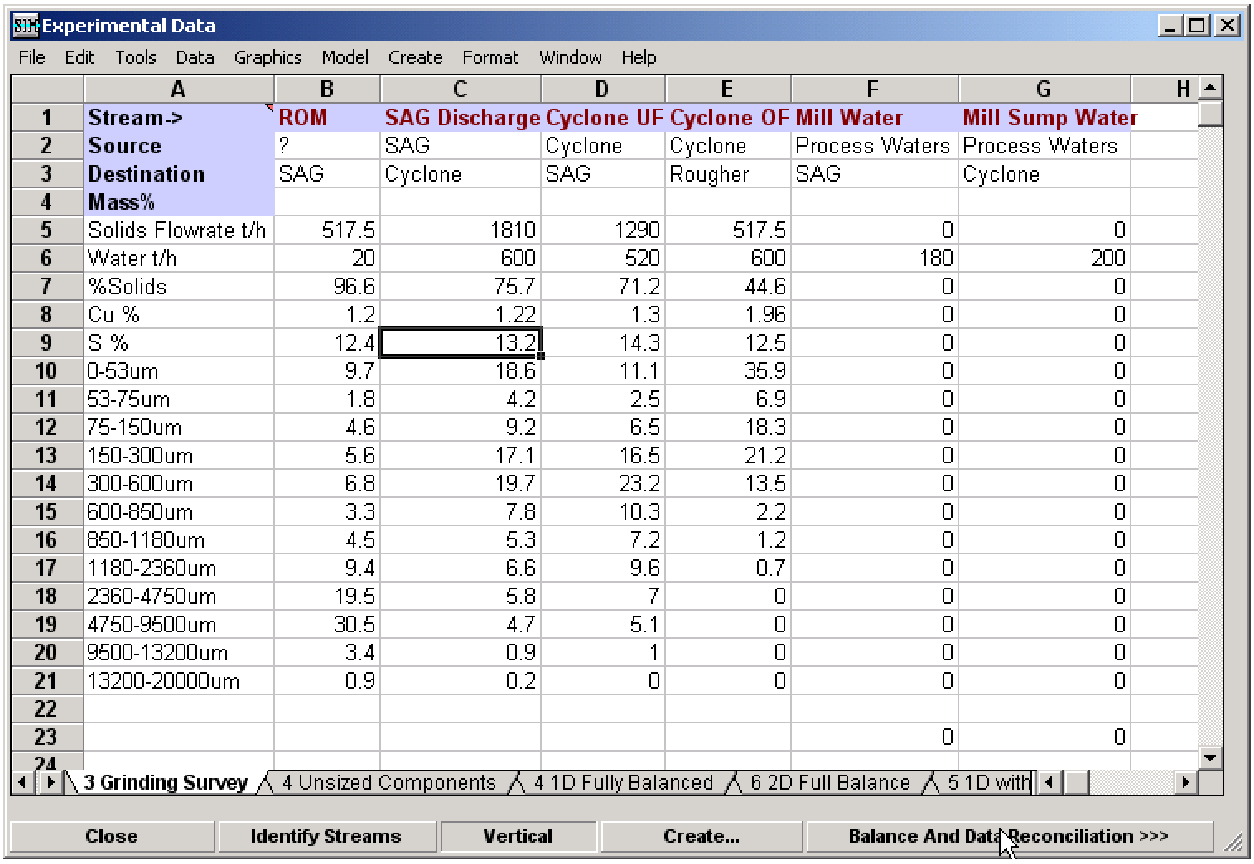
Open the file and select the page "3 Grinding Survey" in the Experimental Data. Check that the data is "Vertical".

Please notice that for the water streams you need to give data also for size distribution (zero values); otherwise the water streams can not be included in the mass balancing. If some of the measured values is zero in all samples (for example the mass proportion of very coarse size fraction) you should take that out in the mass balancing.

Press the **Balance And Data Reconciliation >>>** -button and in the first window uncheck "Cu %" and "S %" (you can later on repeat the example with elemental assays too). In the second step select only streams: “ROM”, “Mill Water”, “Mill Sump Water”, “SAG Discharge”, “Cyclone UF” and “Cyclone OF” (Figure 70). In the following windows you can Skip or just accept by pressing “Next”.

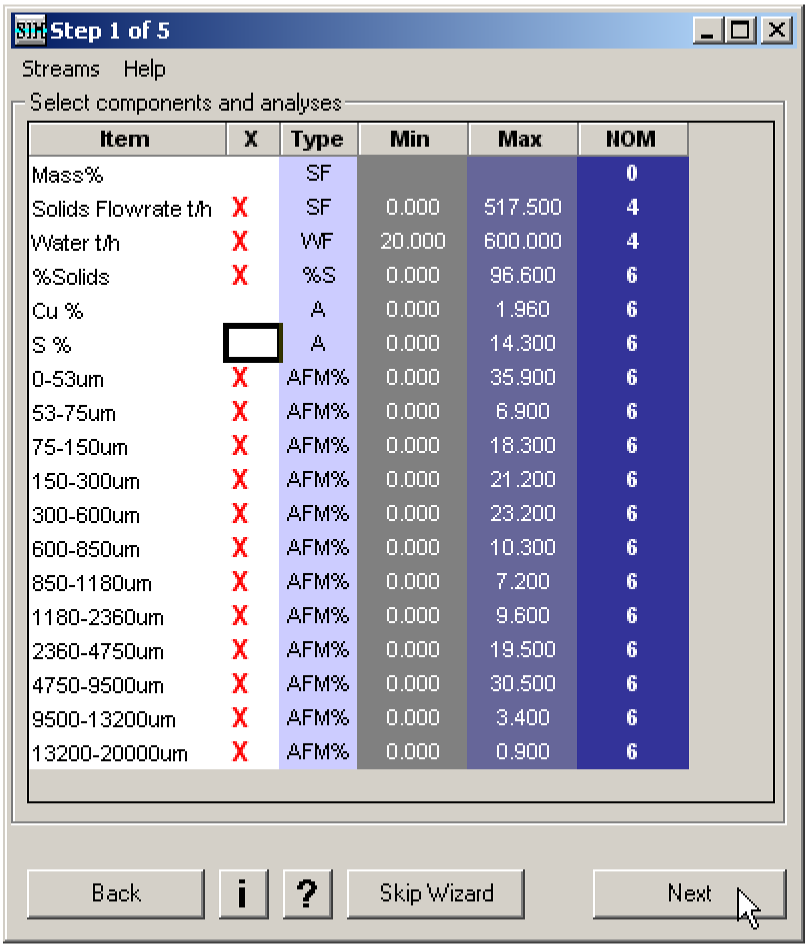
In the “Data Balancing and Reconciliation” window select the data dimension to 1.5D (Figure 71).

Running the mass balance with default options will give negative solid flowrates for the Mill Sump Water (Figure 70). Again, we need to use CLS method. Set min and max values for the “Mill Water” (0 and 0), “Mill Sump Water” (0 and 0). Figure 73 gives the result of the mass balancing. To draw cumulative passing graphs select Graphics – Cumulative Passing (Figure 74 and Figure 75).



	A	B	C	D	E	F	G	H
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	
22								
23						0	0	
24								

Figure 68. 1.5D example: ”3 Grinding Survey” of the Copper Circuit . “Vertical” (on the bottom of the window) indicates that data is vertical, i.e. each sample is a column.



Item	X	Type	Min	Max	NOM
Mass%		SF			0
Solids Flowrate t/h	X	SF	0.000	517.500	4
Water t/h	X	WF	20.000	600.000	4
%Solids	X	%S	0.000	96.600	6
Cu %		A	0.000	1.960	6
S %		A	0.000	14.300	6
0-53um	X	AFM%	0.000	35.900	6
53-75um	X	AFM%	0.000	6.900	6
75-150um	X	AFM%	0.000	18.300	6
150-300um	X	AFM%	0.000	21.200	6
300-600um	X	AFM%	0.000	23.200	6
600-850um	X	AFM%	0.000	10.300	6
850-1180um	X	AFM%	0.000	7.200	6
1180-2360um	X	AFM%	0.000	9.600	6
2360-4750um	X	AFM%	0.000	19.500	6
4750-9500um	X	AFM%	0.000	30.500	6
9500-13200um	X	AFM%	0.000	3.400	6
13200-20000um	X	AFM%	0.000	0.900	6

Figure 69. Select components; uncheck Cu and S in this exercise.

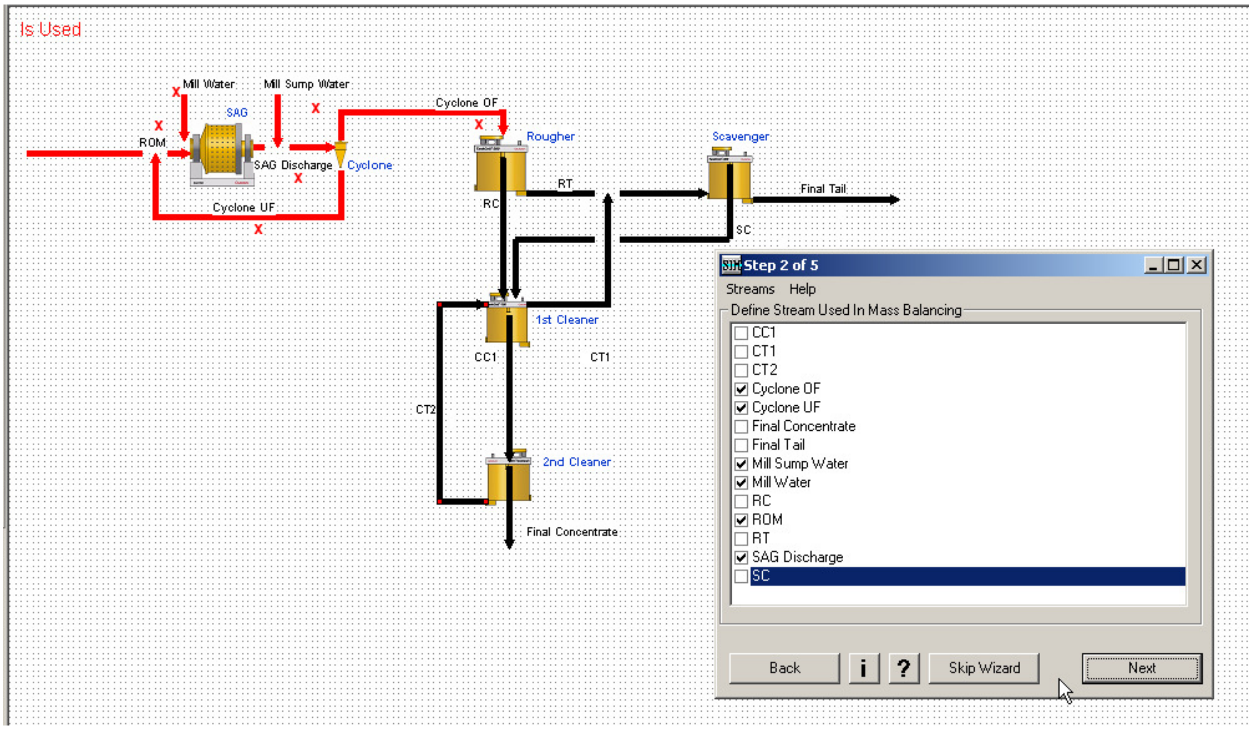


Figure 70. Selections for the streams to be included in the mass balancing.

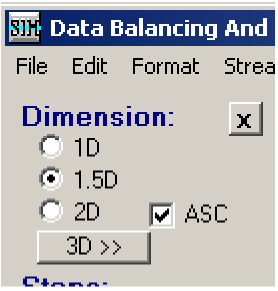


Figure 71. Dimension is 1.5D.

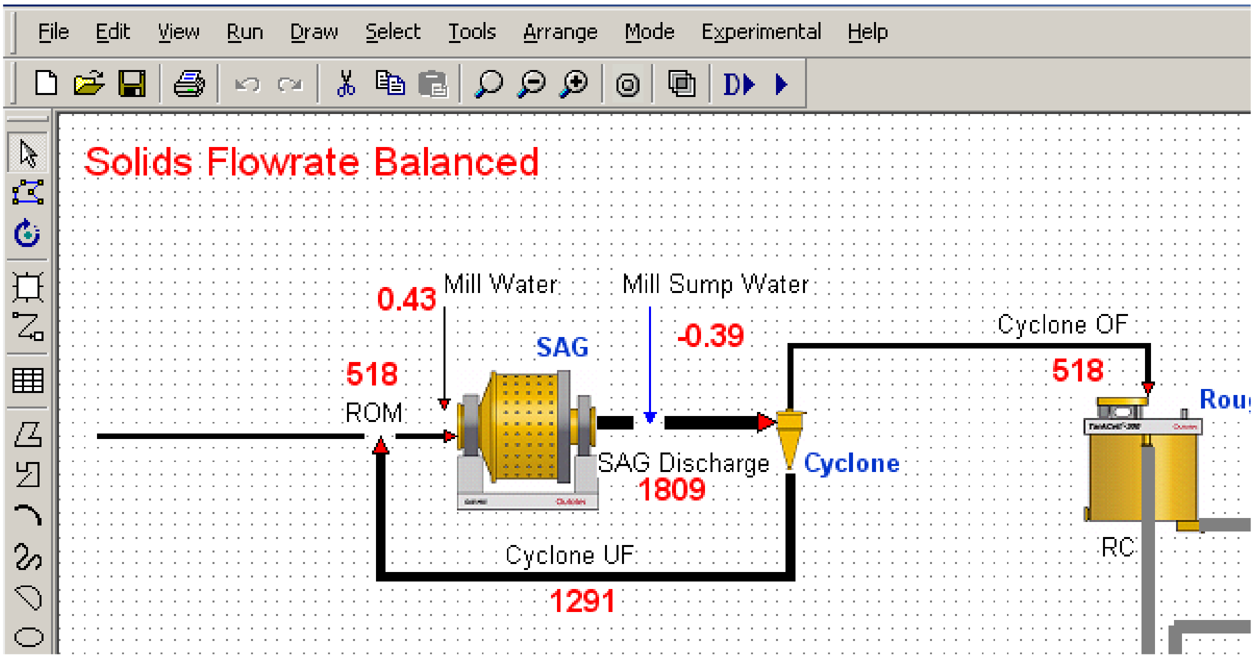


Figure 72. Solution with basic options: negative flowrates.

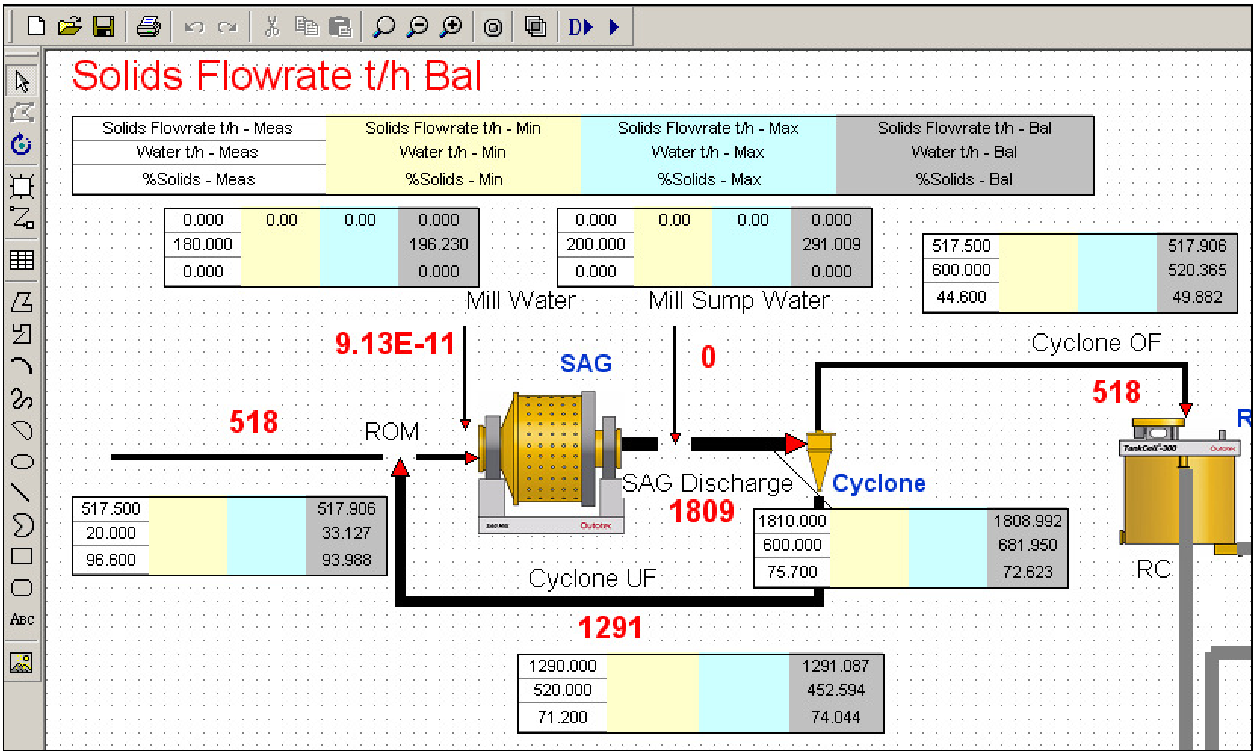


Figure 73. 1.5D Balance result with constraints (min & max).

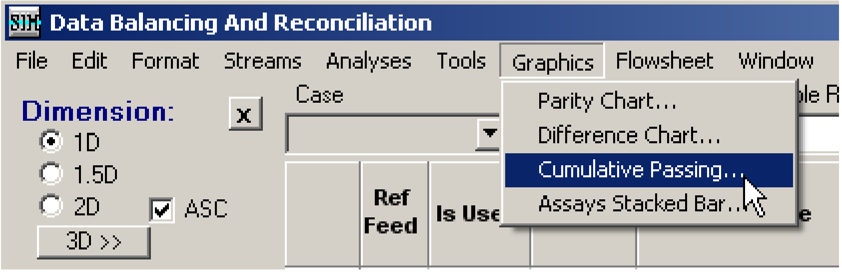


Figure 74. Studying result as cumulative passing graph.

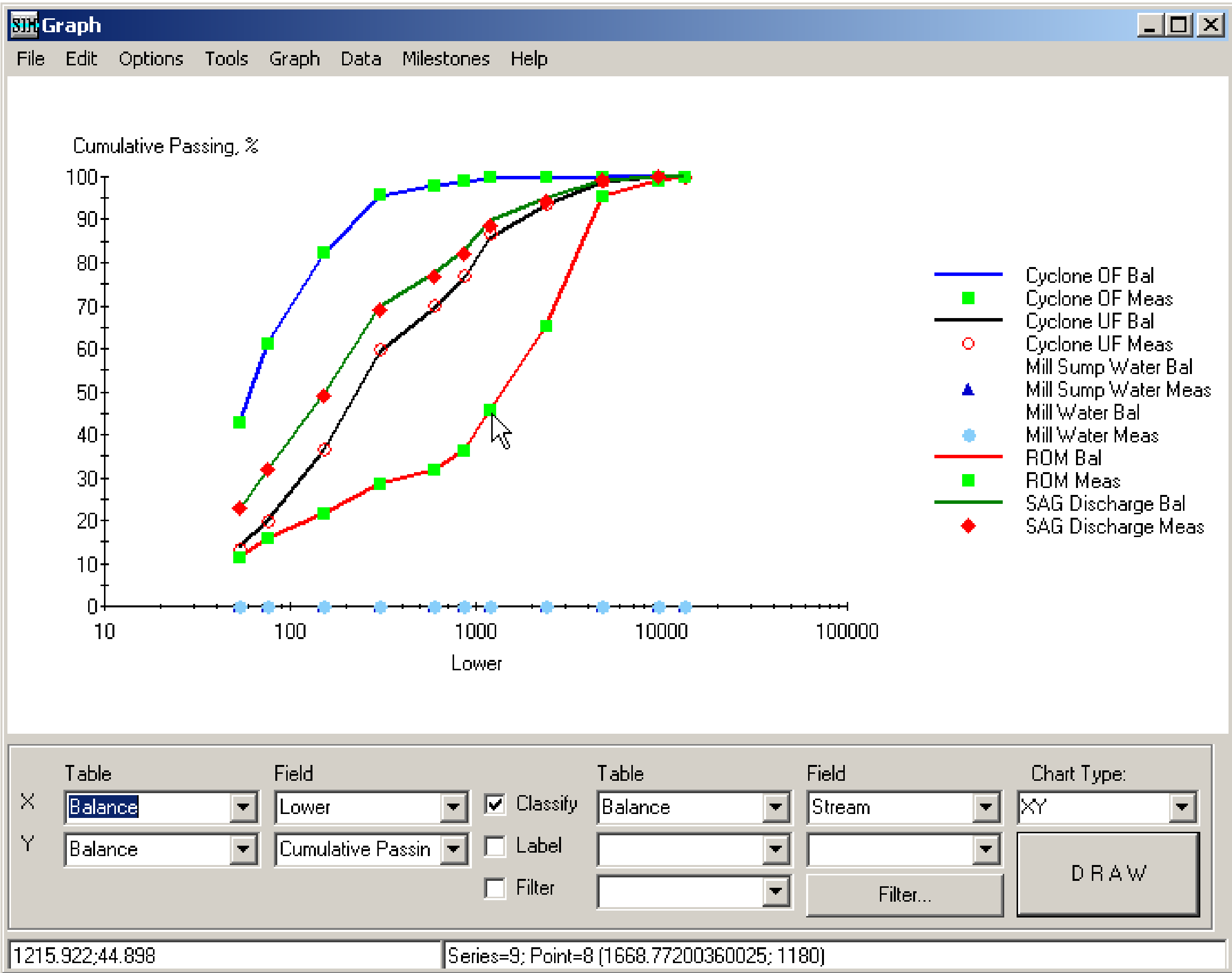


Figure 75. Cumulative passing graph.

49.6. Example 5 – 2D Chemical components

2D example can be found on the sheet "7 2D with ERRORS" in the vary same Copper Circuit flowsheet (Figure 76). Activate the sheet and press **Balance And Data Reconciliation >>>** -button. In the second window uncheck the water streams (Figure 77). Other options you can leave as default (i.e. Skip Wizard). Run the 1D mass balance (Figure 78); in the example NNLS method was used. Once you are happy with the 1D balance, change the dimension to 2D (Figure 79) and run the balance again. Now 2D balance is solved using 1D balance as constraints (Figure 80). Check the difference between balanced and measured with the partity chart (Figure 81, Figure 82). Finally save the results into Experimental Data (Figure 83, Figure 84)

Experimental Data

File Edit Tools Data Graphics Model Create Format Window Help

	A	B	C	D	E	F	G
1	Stream	Source	Destinatio	Solids Re	FractionN	Fraction r	Fraction m
2	ROM	?	SAG		0	Bulk	
3	ROM	?	SAG		1	0-20 um	1.1
4	ROM	?	SAG		2	20-37 um	1.7
5	ROM	?	SAG		3	37-74 um	4.5
6	ROM	?	SAG		4	74-106 um	12
7	ROM	?	SAG		5	106-250 ur	80.7
8	SAG Discharge	SAG	Cyclone		0	Bulk	
9	SAG Discharge	SAG	Cyclone		1	0-20 um	13.7
10	SAG Discharge	SAG	Cyclone		2	20-37 um	9.6
11	SAG Discharge	SAG	Cyclone		3	37-74 um	16.6
12	SAG Discharge	SAG	Cyclone		4	74-106 um	9.8
13	SAG Discharge	SAG	Cyclone		5	106-250 ur	50.3
14	Cyclone UF	Cyclone	SAG		0	Bulk	
15	Cyclone UF	Cyclone	SAG		1	0-20 um	4.5
16	Cyclone UF	Cyclone	SAG		2	20-37 um	3.2
17	Cyclone UF	Cyclone	SAG		3	37-74 um	10.5
18	Cyclone UF	Cyclone	SAG		4	74-106 um	12.9
19	Cyclone UF	Cyclone	SAG		5	106-250 ur	68.9
20	Cyclone OF	Cyclone	Rougher		0	Bulk	
21	Cyclone OF	Cyclone	Rougher		1	0-20 um	39.4
22	Cyclone OF	Cyclone	Rougher		2	20-37 um	24

6 2D Full Balance / 5 1D with ERROR / 7 2D with ERRORS / 8 Several Sets

Figure 76. 2D example.

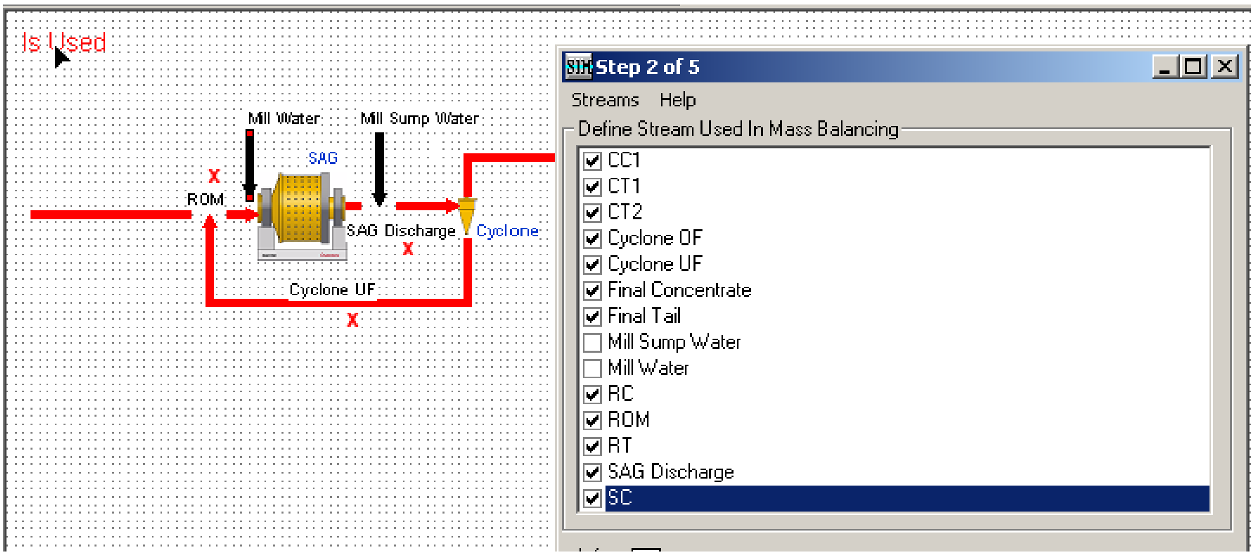


Figure 77. Uncheck Mill Water and Mill Sump Water in the mass balancing.

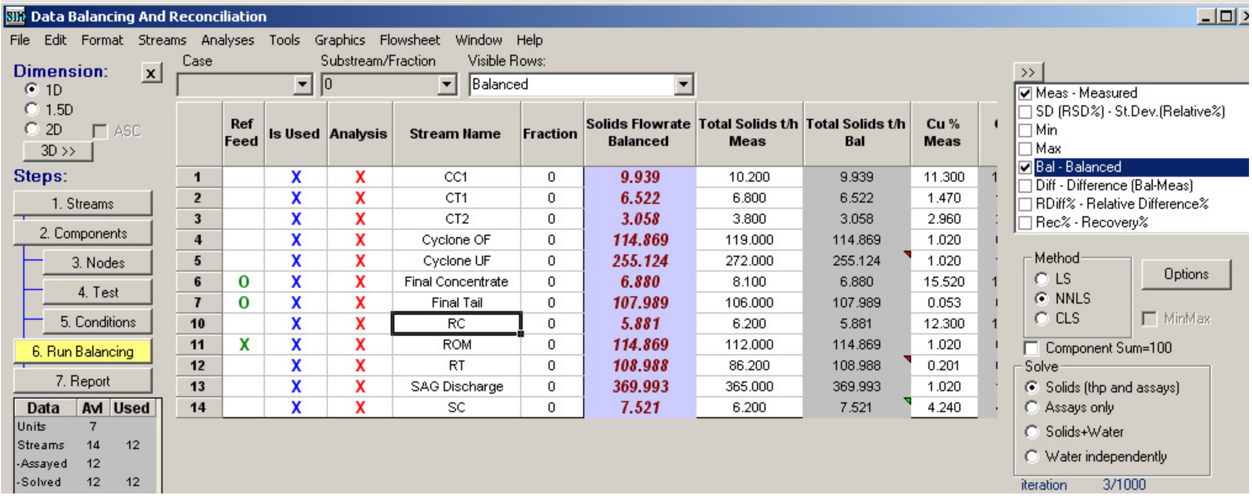


Figure 78. Runnin 1D mass balance with NNLS method.

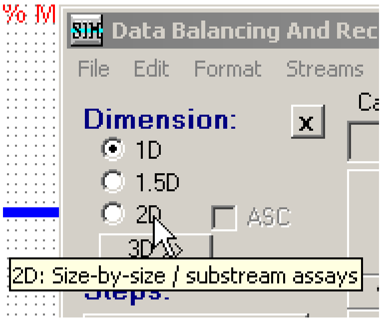


Figure 79. Click 2D.

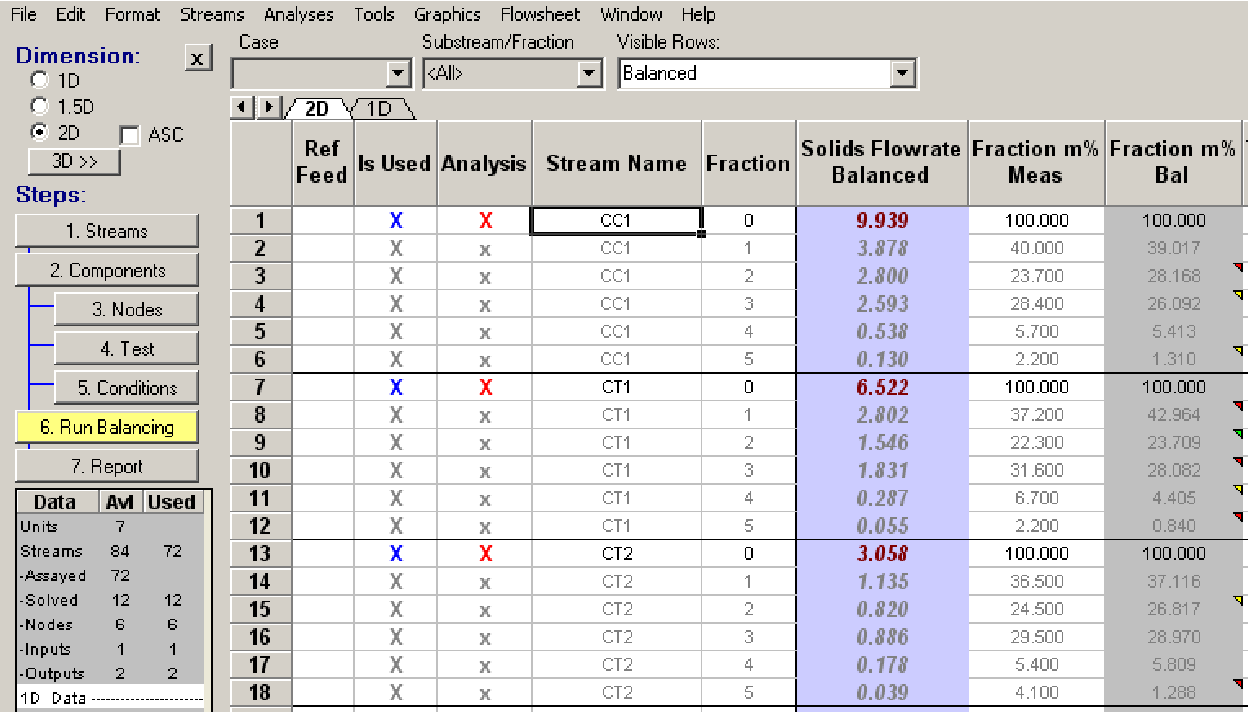


Figure 80. 2D mass balance solved.

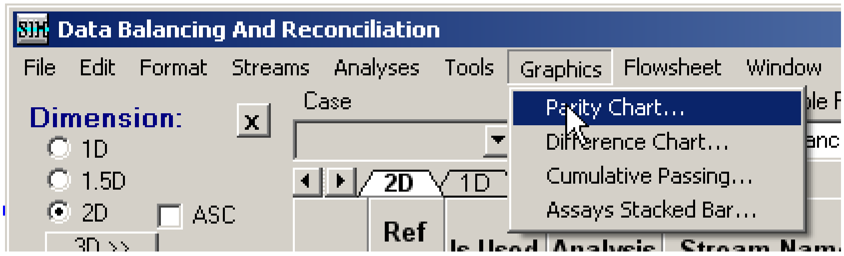


Figure 81. Parity Chart.

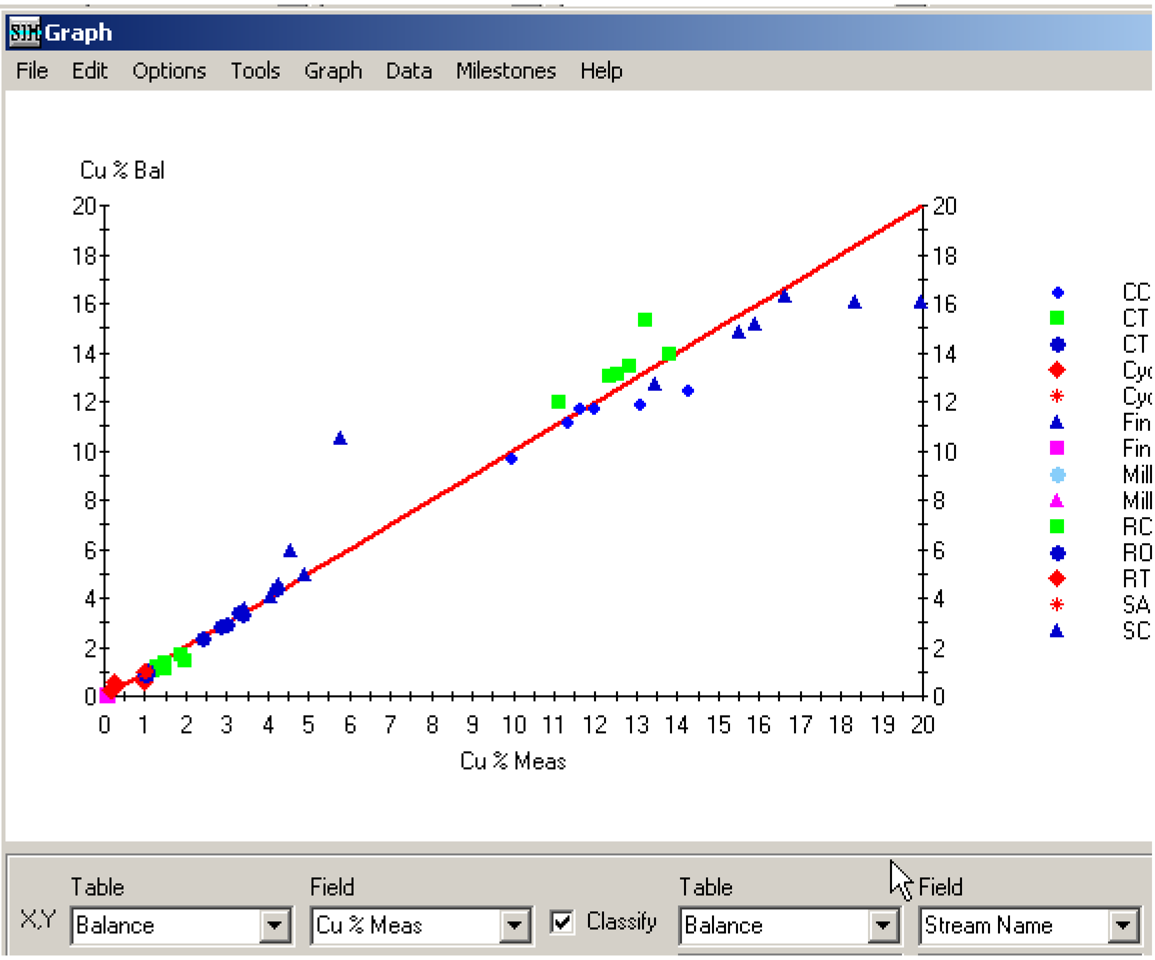


Figure 82. Parity Chart, copper assay, measured vs. balanced.

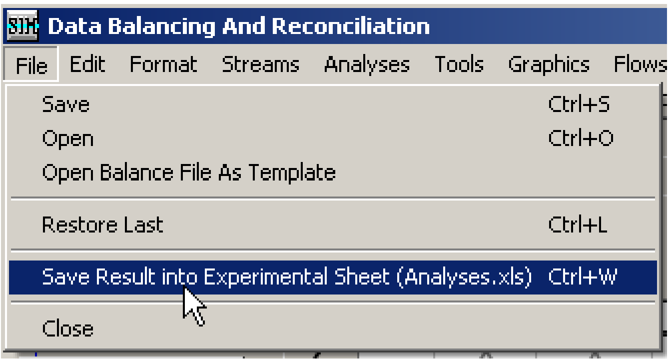
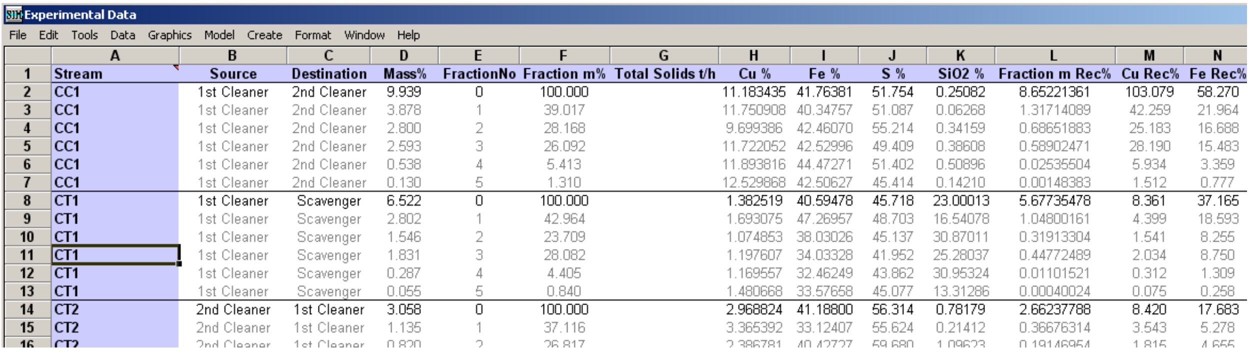


Figure 83. Saving result.



Experimental Data

File Edit Tools Data Graphics Model Create Format Window Help

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1	Stream	Source	Destination	Mass%	FractionNo	Fraction m%	Total Solids t/h	Cu %	Fe %	S %	SiO2 %	Fraction m Rec%	Cu Rec%	Fe Rec%
2	CC1	1st Cleaner	2nd Cleaner	9.939	0	100.000		11.183435	41.76381	51.754	0.25082	8.65221361	103.079	58.270
3	CC1	1st Cleaner	2nd Cleaner	3.878	1	39.017		11.750908	40.34757	51.087	0.06268	1.31714089	42.259	21.964
4	CC1	1st Cleaner	2nd Cleaner	2.800	2	28.168		9.699386	42.46070	55.214	0.34159	0.68651883	25.183	16.688
5	CC1	1st Cleaner	2nd Cleaner	2.593	3	26.092		11.722052	42.52996	49.409	0.38608	0.58902471	28.190	15.483
6	CC1	1st Cleaner	2nd Cleaner	0.538	4	5.413		11.893816	44.47271	51.402	0.50896	0.02535504	5.934	3.359
7	CC1	1st Cleaner	2nd Cleaner	0.130	5	1.310		12.529868	42.50627	45.414	0.14210	0.00148383	1.512	0.777
8	CT1	1st Cleaner	Scavenger	6.522	0	100.000		1.382519	40.59478	45.718	23.00013	5.67735478	8.361	37.165
9	CT1	1st Cleaner	Scavenger	2.802	1	42.964		1.693075	47.26957	48.703	16.54078	1.04800161	4.399	18.593
10	CT1	1st Cleaner	Scavenger	1.546	2	23.709		1.074853	38.03026	45.137	30.87011	0.31913304	1.541	8.255
11	CT1	1st Cleaner	Scavenger	1.831	3	28.082		1.197607	34.03328	41.952	25.28037	0.44772489	2.034	8.750
12	CT1	1st Cleaner	Scavenger	0.287	4	4.405		1.169557	32.46249	43.862	30.95324	0.01101521	0.312	1.309
13	CT1	1st Cleaner	Scavenger	0.055	5	0.840		1.480668	33.57658	45.077	13.31286	0.00040024	0.075	0.258
14	CT2	2nd Cleaner	1st Cleaner	3.058	0	100.000		2.968824	41.18800	56.314	0.78179	2.66237788	8.420	17.683
15	CT2	2nd Cleaner	1st Cleaner	1.135	1	37.116		3.365392	33.12407	55.624	0.21412	0.36676314	3.543	5.278
16	CT2	2nd Cleaner	1st Cleaner	0.820	2	26.817		2.386781	40.42727	59.680	1.09623	0.19146954	1.815	4.655

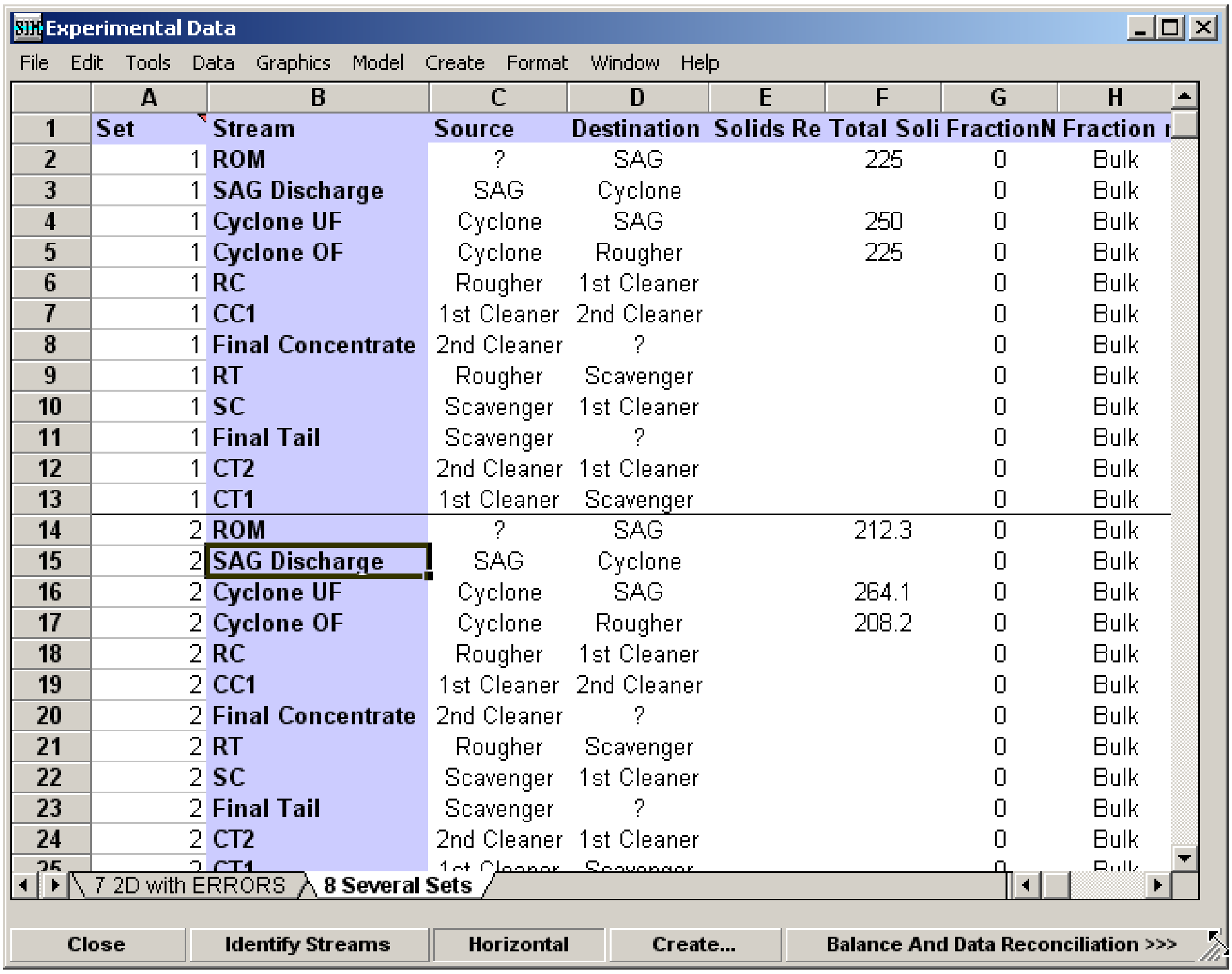
Figure 84. Result in Experimental Data.

49.7. Example 6 – Multiple Data Sets

Multiple data sets example can be found on the sheet "8 Several Sets" in the vary same Copper Circuit flowsheet (Figure 85). Activate the sheet and press **Balance And Data Reconciliation >>>** -button. Use the default options, i.e. press Skip Wizard.

In the Data Balance and Reconciliation window select NNLS method. You can change the other options like standard deviation, sampling error, min and max values, if you like. Press **6. Run Balancing** or **Balance And Reconcile !** button to solve the mass balance. Check the result and if you are happy you can check what is the balance with other cases: change the case in the "Case" combo box (Figure 86). In this exercise the standard deviation for the ROM solids flowrate was set to 0.1.

When you are ready to run all the cases in one go select from the menu "Tools – Solve All Cases" (Figure 87). Give name for the result sheet (Figure 88) and HSC Sim will create the sheet and run the balance for all cases. After finishing the mass balance HSC Sim will show the "Experimental Data", where you can identify the streams (Figure 89), calculate recoveries (Figure 90) and adjust formatting (Figure 91, Figure 92).



	A	B	C	D	E	F	G	H
1	Set	Stream	Source	Destination	Solids Re	Total Soli	FractionN	Fraction
2	1	ROM	?	SAG		225	0	Bulk
3	1	SAG Discharge	SAG	Cyclone			0	Bulk
4	1	Cyclone UF	Cyclone	SAG		250	0	Bulk
5	1	Cyclone OF	Cyclone	Rougher		225	0	Bulk
6	1	RC	Rougher	1st Cleaner			0	Bulk
7	1	CC1	1st Cleaner	2nd Cleaner			0	Bulk
8	1	Final Concentrate	2nd Cleaner	?			0	Bulk
9	1	RT	Rougher	Scavenger			0	Bulk
10	1	SC	Scavenger	1st Cleaner			0	Bulk
11	1	Final Tail	Scavenger	?			0	Bulk
12	1	CT2	2nd Cleaner	1st Cleaner			0	Bulk
13	1	CT1	1st Cleaner	Scavenger			0	Bulk
14	2	ROM	?	SAG		212.3	0	Bulk
15	2	SAG Discharge	SAG	Cyclone			0	Bulk
16	2	Cyclone UF	Cyclone	SAG		264.1	0	Bulk
17	2	Cyclone OF	Cyclone	Rougher		208.2	0	Bulk
18	2	RC	Rougher	1st Cleaner			0	Bulk
19	2	CC1	1st Cleaner	2nd Cleaner			0	Bulk
20	2	Final Concentrate	2nd Cleaner	?			0	Bulk
21	2	RT	Rougher	Scavenger			0	Bulk
22	2	SC	Scavenger	1st Cleaner			0	Bulk
23	2	Final Tail	Scavenger	?			0	Bulk
24	2	CT2	2nd Cleaner	1st Cleaner			0	Bulk
25	2	CT1	1st Cleaner	Scavenger			0	Bulk

Figure 85. Data with several sets; Sheet "8 Several Sets".

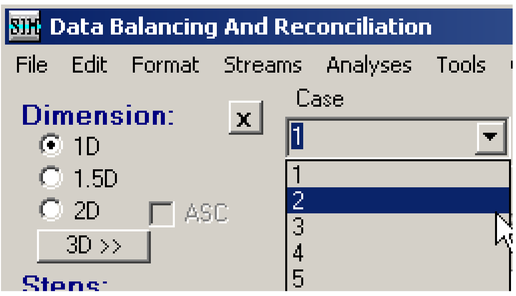


Figure 86. Changing to second case.

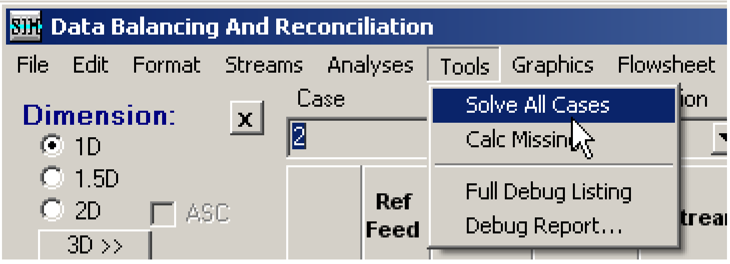


Figure 87. Solving all cases.

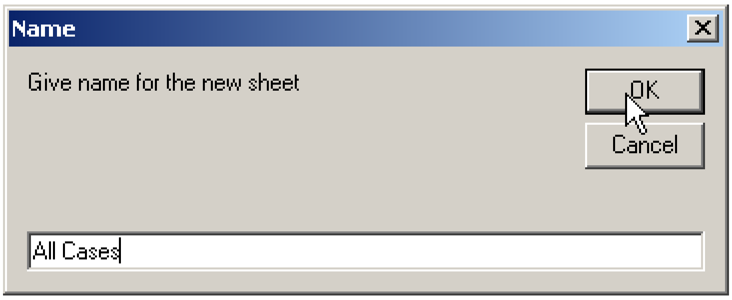


Figure 88. Naming the result sheet.

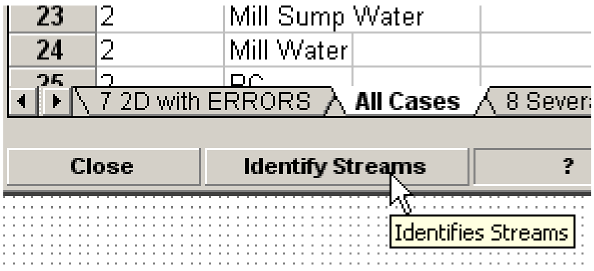


Figure 89. Identify Streams and …

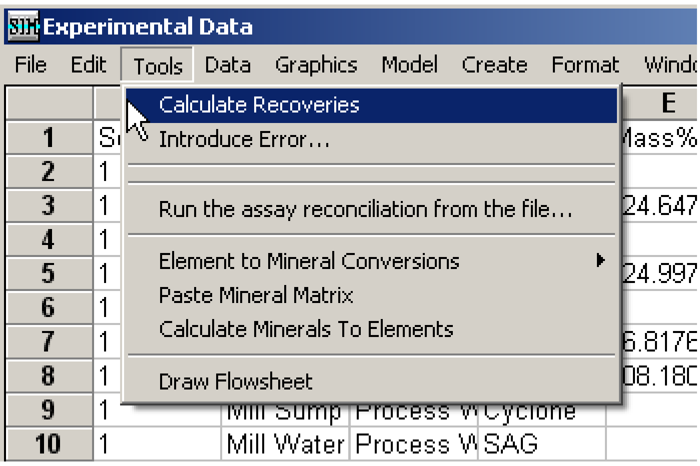


Figure 90. … calculate the recoveries.

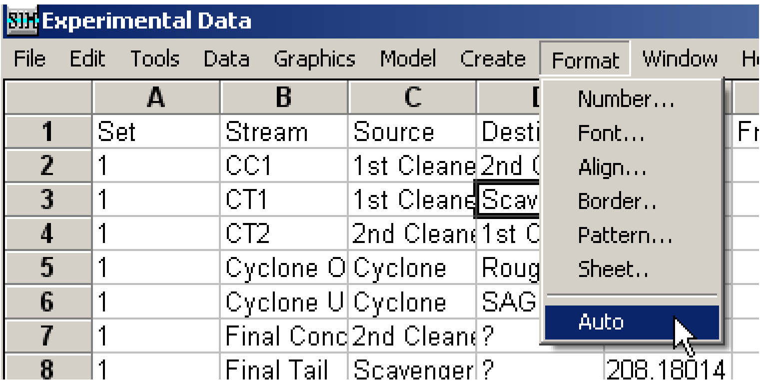
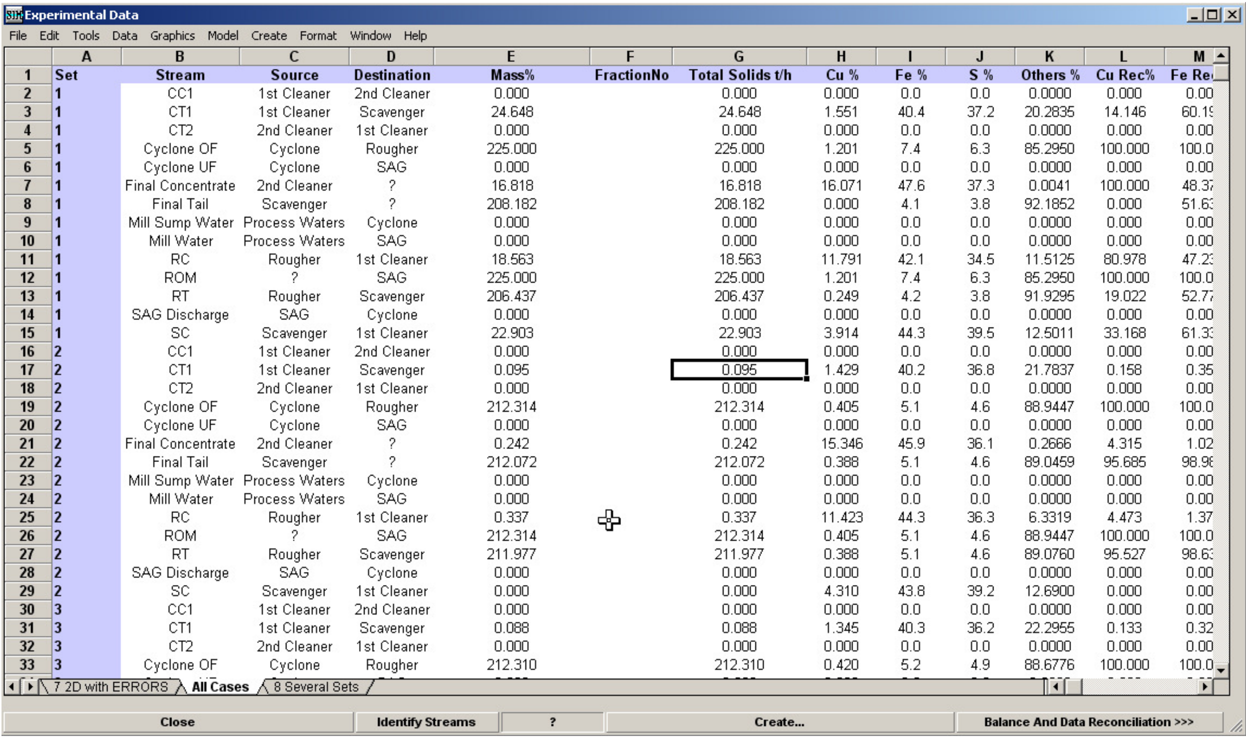


Figure 91. Formatting the result sheet.



	Set	Stream	Source	Destination	Mass%	FractionNo	Total Solids t/h	Cu %	Fe %	S %	Others %	Cu Rec%	Fe Re
2	1	CC1	1st Cleaner	2nd Cleaner	0.000		0.000	0.000	0.0	0.0	0.0000	0.000	0.00
3	1	CT1	1st Cleaner	Scavenger	24.648		24.648	1.551	40.4	37.2	20.2835	14.146	60.1
4	1	CT2	2nd Cleaner	1st Cleaner	0.000		0.000	0.000	0.0	0.0	0.0000	0.000	0.00
5	1	Cyclone OF	Cyclone	Rougher	225.000		225.000	1.201	7.4	6.3	85.2950	100.000	100.0
6	1	Cyclone UF	Cyclone	SAG	0.000		0.000	0.000	0.0	0.0	0.0000	0.000	0.00
7	1	Final Concentrate	2nd Cleaner	?	16.818		16.818	16.071	47.6	37.3	0.0041	100.000	48.3
8	1	Final Tail	Scavenger	?	208.182		208.182	0.000	4.1	3.8	92.1852	0.000	51.6
9	1	Mill Sump Water	Process Waters	Cyclone	0.000		0.000	0.000	0.0	0.0	0.0000	0.000	0.00
10	1	Mill Water	Process Waters	SAG	0.000		0.000	0.000	0.0	0.0	0.0000	0.000	0.00
11	1	RC	Rougher	1st Cleaner	18.563		18.563	11.791	42.1	34.5	11.5125	80.978	47.2
12	1	ROM	?	SAG	225.000		225.000	1.201	7.4	6.3	85.2950	100.000	100.0
13	1	RT	Rougher	Scavenger	206.437		206.437	0.249	4.2	3.8	91.9295	19.022	52.7
14	1	SAG Discharge	SAG	Cyclone	0.000		0.000	0.000	0.0	0.0	0.0000	0.000	0.00
15	1	SC	Scavenger	1st Cleaner	22.903		22.903	3.914	44.3	39.5	12.5011	33.168	61.3
16	2	CC1	1st Cleaner	2nd Cleaner	0.000		0.000	0.000	0.0	0.0	0.0000	0.000	0.00
17	2	CT1	1st Cleaner	Scavenger	0.095		0.095	1.429	40.2	36.8	21.7837	0.158	0.35
18	2	CT2	2nd Cleaner	1st Cleaner	0.000		0.000	0.000	0.0	0.0	0.0000	0.000	0.00
19	2	Cyclone OF	Cyclone	Rougher	212.314		212.314	0.405	5.1	4.6	88.9447	100.000	100.0
20	2	Cyclone UF	Cyclone	SAG	0.000		0.000	0.000	0.0	0.0	0.0000	0.000	0.00
21	2	Final Concentrate	2nd Cleaner	?	0.242		0.242	15.346	45.9	36.1	0.2666	4.315	1.02
22	2	Final Tail	Scavenger	?	212.072		212.072	0.388	5.1	4.6	89.0459	95.685	98.9
23	2	Mill Sump Water	Process Waters	Cyclone	0.000		0.000	0.000	0.0	0.0	0.0000	0.000	0.00
24	2	Mill Water	Process Waters	SAG	0.000		0.000	0.000	0.0	0.0	0.0000	0.000	0.00
25	2	RC	Rougher	1st Cleaner	0.337		0.337	11.423	44.3	36.3	6.3319	4.473	1.37
26	2	ROM	?	SAG	212.314		212.314	0.405	5.1	4.6	88.9447	100.000	100.0
27	2	RT	Rougher	Scavenger	211.977		211.977	0.388	5.1	4.6	89.0760	95.527	98.6
28	2	SAG Discharge	SAG	Cyclone	0.000		0.000	0.000	0.0	0.0	0.0000	0.000	0.00
29	2	SC	Scavenger	1st Cleaner	0.000		0.000	4.310	43.8	39.2	12.6900	0.000	0.00
30	3	CC1	1st Cleaner	2nd Cleaner	0.000		0.000	0.000	0.0	0.0	0.0000	0.000	0.00
31	3	CT1	1st Cleaner	Scavenger	0.088		0.088	1.345	40.3	36.2	22.2955	0.133	0.32
32	3	CT2	2nd Cleaner	1st Cleaner	0.000		0.000	0.000	0.0	0.0	0.0000	0.000	0.00
33	3	Cyclone OF	Cyclone	Rougher	212.310		212.310	0.420	5.2	4.9	88.6776	100.000	100.0

Figure 92. The result.