REFERENCES

Biswas, A.K.; and Davenport, W.G. *Extractive Metallurgy of Copper.* 3rd ed. Elsevier Science, 1994.

Caletones Smelter, El Teniente Division. *Mass and Heat Balance Model for Teniente Converter* [Power point presentation file]. Training document of Codelco, Chile, 2003.

El Teniente Division, Codelco. *Teniente Converter Operation Manual.* Rayong: Thai Copper Smelter, 2007. (Unpublished Manuscript)

Davies, A.L.; Castle, J.F.; Gabb, P.J.; Siraa, M.A.S.; Gisby, J.A.; and Weddick, A.J. Thermochemical modeling of smelting operations. In C. Diaz; C. Landolt and T. Utigard (eds.), *Preceedings of the Copper 99 – Cobre 99 International conference – Vol.VI: Smelting, Technology Development, Process Modeling and Fundamentals* (1999): 309-321.

Díaz, C.; Thermodynamic Properties of Copper Slag Systems. *INCRA Monograph Series III* (1974): 132.

Díaz, C.; Schwarze, H.; and Taylor, J.C. The Changing Landscape of Copper Smelting in the Americas. *Copper 95 – Cobre95 Vol. IV: Pyrometallurgy of Copper* (1995): 3-28.

Fakeeha, A.H.; Wagialla, K.M.; and El-Dahshan, M.E. Thechnoeconomics Study for Production of Copper from Saudi Ore. *Engineering Costs and Production Economics* 18(1990): 275-283.

Luraschi, A.; and Cañas, J.D. *Thermodynamic Fundamentals of Teniente Converter Smelting*. Santiago, Chile: CADE IDEPE, 1997. (Mimeographed)

Luraschi, A.; Riveros, G.; Cerna, M.; and Bustos, R. The Behavior of Impurities in Copper Smelting. *CIMM project for Chuquicamata Division of CODELCO-Chile Final Report* (1994): 5004.

Luraschi, A.; Riveros, G.; Cerna, M.; and Bustos, R. Development and application of CTIMP software for the modelling of impurity behavior in the Teniente

Converter. *CIMM project for El Teniente Division of CODELCO-Chile Final Report* (1994): 994.

Mackey, P.J.; and Campos R. Modern Continuous Smelting and Converting by Bath Smelting Technology. *Canadian Metallurgical Quarterly* 40(2001): 355-376.

Moskalyk, R.R.; and Alfantazi, A.M. Review of copper pyrometallurgical practice: today and tomorrow. *Mineral Engineering* 16(2003): 893-919.

Nagamori, N.; and Mackey, P.J. Thermodynamics of Copper Matte Converting. *Part I. Met. Trans. B.* 9B (1978): 255-65.

Otero, A.; and Luraschi, A. Development of an Equilibrium Impurity Distribution Model of the Teniente Converter. *CIMM project for Teniente Division of CODELCO-Chile Final Report* (1987): 415.

Ramachandran, R.; Diaz, C.; Eltringham, T; Jiang, C.Y.; Lehner, T.; Mackey, P.J.; Newman, C.J.; and Tarasov, A. Primary Copper production-a survey of operating world copper [Acrobat reader file]. AZ, USA, 2003.

Rosales, M.; Ruz, P.; Fuentes, R.; and Moyano, A. Oxygen Efficiency Calculation in Teniente Converters. In C. Diaz; C. Landolt; and T. Utigard (eds), *Copper 2003 – Cobre 2003 The Hermann Schwarze Symposium on Copper Pyrometallurgy, Vol. VI – Pyrometallurgy of Copper* (2003): 241-249.

Siraa, M.A.S.; Davises, A.L.; Gabb, P.J.; and Weddick, A.J. Process Modeling for KUCC smelter studies and on-line furnace control. *Preceedings of the Copper 99 – Cobre 99 International conference – Vol. VI : Smelting, Technology Development, Process Modeling and Fundamentals* (1999): 349-360.

Smelter and Refinery Project: Teniente Converter Process Calculation Final Report, Chile: Codelco – El Teniente Division, 1996.

Sridhar, R.; Toguri, J.M.; and Simeonov, S. Copper Losses and Thermodynamic Considerations in Copper Smelting. *Metall. Trans. B* 28B(1997): 191-200.

APPENDICES

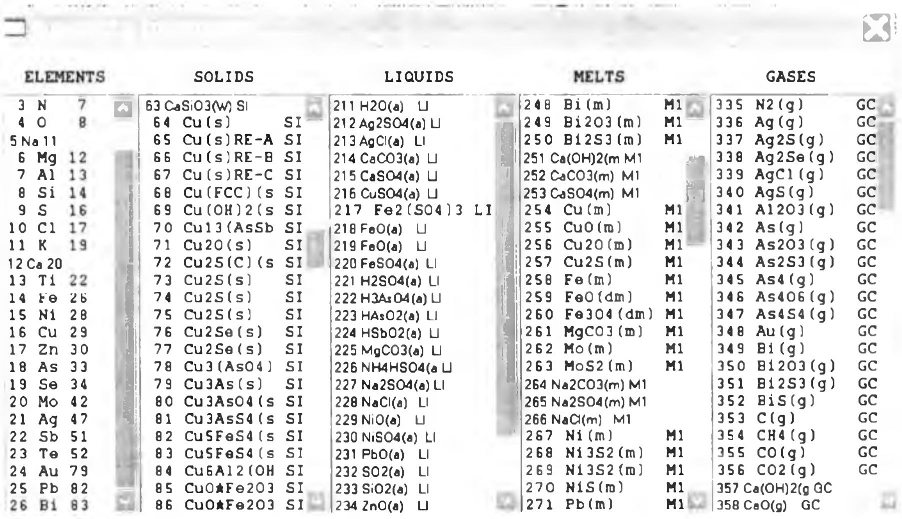
APPENDIX A

BUILDING A PSR MODEL IN METSIM

The steps for building a PSR model using METSIM software can be described as follows:

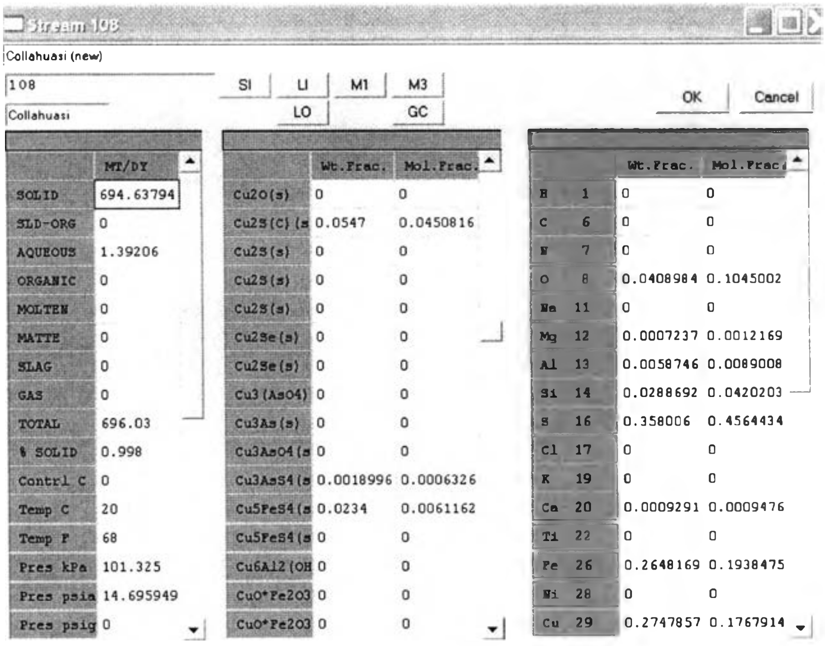
(1) Select the elements and compounds to be included in the database (Figure A-1). The principle elements to be considered are Cu, Fe, S, O, Si and N. Main compounds are Cu_2S, FeS, FeO, Fe_3O_4, Fe_2SiO_4, Cu_2O, SiO_2, SO_2, and N_2. Others elements and compounds are included in this model to describe the impurity distribution from the raw material.

(2) Specify the amounts (flow rates) and compositions of input streams and humidity in the first column (Figure A-2). Adjust the mineralogical composition of a copper concentrate to be compatible with the chemical assays in the second column. It is noted that the first column needs to be filled in before the user can fill in other columns. The last column shows the elemental composition which the program calculates automatically from the second column.



ELEMENTS	SOLIDS	LIQUIDS	MELTS	GASES
3 N 7	63 CaSiO3(W) SI	211 H2O(a) LI	248 Bi(m) M1	335 N2(g) GC
4 O 8	64 Cu(s) SI	212 Ag2SO4(a) LI	249 Bi2O3(m) M1	336 Ag(g) GC
5 Na 11	65 Cu(s)RE-A SI	213 AgCl(a) LI	250 Bi2S3(m) M1	337 Ag2S(g) GC
6 Mg 12	66 Cu(s)RE-B SI	214 CaCO3(a) LI	251 Ca(OH)2(m M1	338 Ag2Se(g) GC
7 Al 13	67 Cu(s)RE-C SI	215 CaSO4(a) LI	252 CaCO3(m) M1	339 AgCl(g) GC
8 Si 14	68 Cu(FCC)(s SI	216 CuSO4(a) LI	253 CaSO4(m) M1	340 AgS(g) GC
9 S 16	69 Cu(OH)2(s SI	217 Fe2(SO4)3 LI	254 Cu(m) M1	341 Al2O3(g) GC
10 Cl 17	70 Cu13(AsSb SI	218 FeO(a) LI	255 CuO(m) M1	342 As(g) GC
11 K 19	71 Cu2O(s) SI	219 FeO(a) LI	256 Cu2O(m) M1	343 As2O3(g) GC
12 Ca 20	72 Cu2S(C)(s SI	220 FeSO4(a) LI	257 Cu2S(m) M1	344 As2S3(g) GC
13 Ti 22	73 Cu2S(s) SI	221 H2SO4(a) LI	258 Fe(m) M1	345 As4(g) GC
14 Fe 26	74 Cu2S(s) SI	222 H3AsO4(a) LI	259 FeO(dm) M1	346 As4O6(g) GC
15 Ni 28	75 Cu2S(s) SI	223 HAsO2(a) LI	260 Fe3O4(dm) M1	347 As4S4(g) GC
16 Cu 29	76 Cu2Se(s) SI	224 HSbO2(a) LI	261 MgCO3(m) M1	348 Au(g) GC
17 Zn 30	77 Cu2Se(s) SI	225 MgCO3(a) LI	262 Mo(m) M1	349 Bi(g) GC
18 As 33	78 Cu3(AsO4) SI	226 NH4HSO4(a LI	263 MoS2(m) M1	350 Bi2O3(g) GC
19 Se 34	79 Cu3As(s) SI	227 Na2SO4(a) LI	264 Na2CO3(m) M1	351 Bi2S3(g) GC
20 Mo 42	80 Cu3AsO4(s SI	228 NaCl(a) LI	265 Na2SO4(m) M1	352 BiS(g) GC
21 Ag 47	81 Cu3AsS4(s SI	229 NiO(a) LI	266 NaCl(m) M1	353 C(g) GC
22 Sb 51	82 Cu5FeS4(s SI	230 NiSO4(a) LI	267 Ni(m) M1	354 CH4(g) GC
23 Te 52	83 Cu5FeS4(s SI	231 PbO(a) LI	268 Ni3S2(m) M1	355 CO(g) GC
24 Au 79	84 Cu6Al2(OH SI	232 SO2(a) LI	269 Ni3S2(m) M1	356 CO2(g) GC
25 Pb 82	85 CuO*Fe2O3 SI	233 SiO2(a) LI	270 NiS(m) M1	357 Ca(OH)2(g GC
26 Bi 83	86 CuO*Fe2O3 SI	234 ZnO(a) LI	271 Pb(m) M1	358 CaO(g) GC

Figure A-1: Elements and Compounds which are shown in METSIM program



Collahuasi (new)

108

Collahuasi

	MT/DY
SOLID	694.63794
SLD-ORG	0
AQUEOUS	1.39206
ORGANIC	0
MOLTEN	0
MATTE	0
SLAG	0
GAS	0
TOTAL	696.03
% SOLID	0.998
Contrl C	0
Temp C	20
Temp F	68
Pres kPa	101.325
Pres psia	14.695949
Pres psig	0

	Wt.Frac.	Mol.Frac.
Cu2O(s)	0	0
Cu2S(C)(s	0.0547	0.0450816
Cu2S(s)	0	0
Cu2S(s)	0	0
Cu2S(s)	0	0
Cu2Se(s)	0	0
Cu2Se(s)	0	0
Cu3(AsO4)	0	0
Cu3As(s)	0	0
Cu3AsO4(s	0	0
Cu3AsS4(s	0.0018996	0.0006326
Cu5FeS4(s	0.0234	0.0061162
Cu5FeS4(s	0	0
Cu6Al2(OH	0	0
CuO*Fe2O3	0	0
CuO*Fe2O3	0	0

		Wt.Frac.	Mol.Frac.
H	1	0	0
C	6	0	0
N	7	0	0
O	8	0.0408984	0.1045002
Na	11	0	0
Mg	12	0.0007237	0.0012169
Al	13	0.0058746	0.0089008
Si	14	0.0288692	0.0420203
S	16	0.358006	0.4564434
Cl	17	0	0
K	19	0	0
Ca	20	0.0009291	0.0009476
Ti	22	0	0
Fe	26	0.2648169	0.1938475
Ni	28	0	0
Cu	29	0.2747857	0.1767914

Figure A-2: Flow rate and composition which are required for input stream

(3) Draw all the units and insert input and output streams. In this study, a FRL furnace is used as a primary smelting reactor (PSR) (Figure A-3).

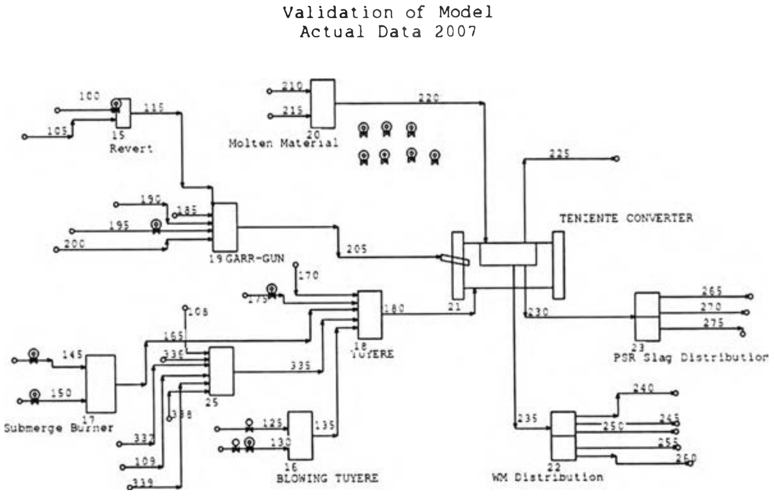
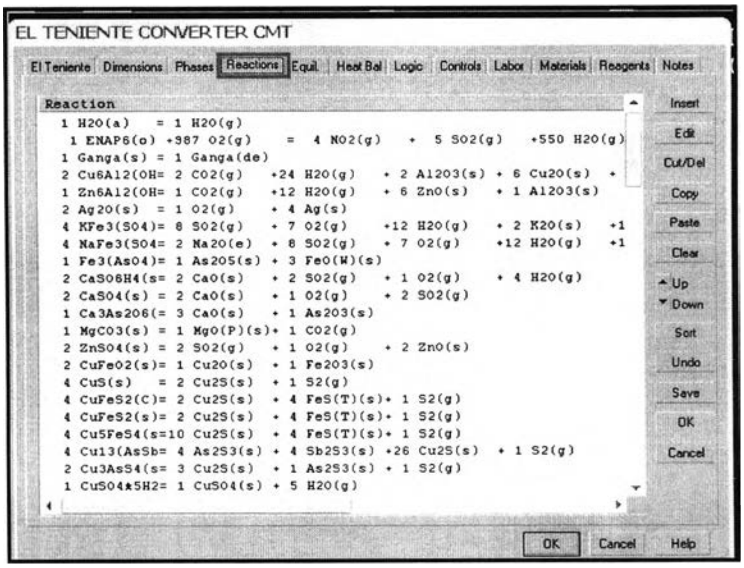


Figure A-3: PSR Model in METSIM

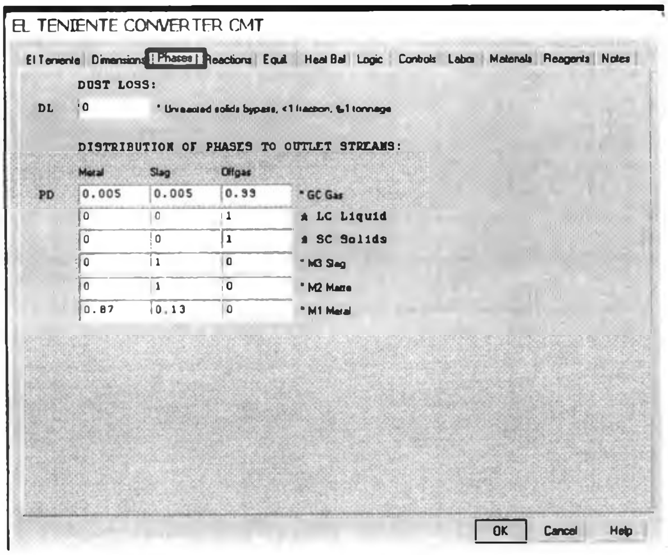


```
Reaction
 1 H2O(a)    = 1 H2O(g)
  1 ENAP6(o) +987 O2(g)     =  4 NO2(g)   +  5 SO2(g)   +550 H2O(g)
 1 Ganga(s) = 1 Ganga(de)
 2 Cu6A12(OH= 2 CO2(g)   +24 H2O(g)   + 2 A12O3(s) + 6 Cu2O(s)  +
 1 Zn6A12(OH= 1 CO2(g)   +12 H2O(g)   + 6 ZnO(s)   + 1 A12O3(s)
 2 Ag2O(s)   = 1 O2(g)    + 4 Ag(s)
 4 KFe3(SO4)= 8 SO2(g)   + 7 O2(g)    +12 H2O(g)   + 2 K2O(s)   +1
 4 NaFe3(SO4= 2 Na2O(e)  + 8 SO2(g)   + 7 O2(g)    +12 H2O(g)   +1
 1 Fe3(AsO4)= 1 As2O5(s) + 3 FeO(W)(s)
 2 CaSO6H4(s= 2 CaO(s)   + 2 SO2(g)   + 1 O2(g)    + 4 H2O(g)
 2 CaSO4(s) = 2 CaO(s)   + 1 O2(g)    + 2 SO2(g)
 1 Ca3As2O6(= 3 CaO(s)   + 1 As2O3(s)
 1 MgCO3(s) = 1 MgO(P)(s)+ 1 CO2(g)
 2 ZnSO4(s) = 2 SO2(g)   + 1 O2(g)    + 2 ZnO(s)
 2 CuFeO2(s)= 1 Cu2O(s)  + 1 Fe2O3(s)
 4 CuS(s)    = 2 Cu2S(s)  + 1 S2(g)
 4 CuFeS2(C)= 2 Cu2S(s)  + 4 FeS(T)(s)+ 1 S2(g)
 4 CuFeS2(s)= 2 Cu2S(s)  + 4 FeS(T)(s)+ 1 S2(g)
 4 Cu5FeS4(s=10 Cu2S(s)  + 4 FeS(T)(s)+ 1 S2(g)
 4 Cu13(AsSb= 4 As2S3(s) + 4 Sb2S3(s) +26 Cu2S(s)  + 1 S2(g)
 2 Cu3AsS4(s= 3 Cu2S(s)  + 1 As2S3(s) + 1 S2(g)
 1 CuSO4*5H2= 1 CuSO4(s) + 5 H2O(g)
```

Figure A-4: Input reaction and extent of reaction in PSR reactor

(4) Define chemical reactions together with the reaction sequence and assign the degree of reactions (Figure A-4).

(5) Assign the distribution coefficients of each phase for all process streams (Figure A-5). For example, 20% of matte contaminates in slag stream. The total number of phases that can be specified is 8 as shown in Table A-1. The chemical species such as pure chemicals, minerals or elements, can exist in one or more of eight phases.



DUST LOSS:

DL 0 * Unreacted solids bypass, <1 fraction, ≥1 tonnage

DISTRIBUTION OF PHASES TO OUTLET STREAMS:

	Metal	Slag	Offgas	
PD	0.005	0.005	0.99	* GC Gas
	0	0	1	* LC Liquid
	0	0	1	* SC Solids
	0	1	0	* M3 Slag
	0	1	0	* M2 Matte
	0.87	0.13	0	* M1 Metal

Figure A-5: Input distribution coefficient in PSR reactor

Table A-1: All phases in a PRS model

Component	Phase	Phase No.	Types of components
Solid Components	SC		Includes SI & SO
Solid Inorganic	SI	1	Minerals, Salts
Solid Organic	SO	2	Coal, Resin, Carbon
Fluid Components	FC		Includes LC & GC
Liquid Components	LC		Includes LI, LO, M1, M2 & M3
Liquids Inorganic	LI	3	Water, Acids, Dissolved Salts
Liquid Organic	LO	4	Fuel, Kerosene, Organics
Molten 1	M1	5	Molten Metals, Speiss
Molten 2	M2	6	Molten Sulfides, Halides
Molten 3	M3	7	Molten Oxides, Slags
Gaseous components	GC	8	Air, Gaseous, Metal Vapors

METSIM carries out mass balance calculations by tracking material flows. The phases are identified by their phase number. Prior to using any of the component input routines, a comprehensive list of the components is first prepared. Components are assigned to the phases in which they are present.

(6). Add all information required in each tab. It should be noted that the data of reactions and the extent of reactions are required as the input in METSIM. A modeler should know the correct reactions in the PSR and their extent of reactions (either in an exact value or in an expression) in order to obtain a appropriate reactor model.

APPENDIX B

REACTIONS IN A PRIMARY SMELTING REACTOR

The reactions in a primary smelting reactor and their extent of the reactions are shown as follows;

No.	Reaction			Extent
1	$H_2O(aq)$	$\Rightarrow$	$H_2O(g)$	1
2	1 Gangue(s)	$\Rightarrow$	1Gangue(sl)	1
3	$2Cu_6Al_2(OH)(s)$	$\Rightarrow$	$1CO_2(g) + 12H_2O(g) + 6ZnO(s)$ $+ Al_2O_3(s)$	1
4	$Zn_6Al_{12}(OH)(s)$	$\Rightarrow$	$1CO_2(g) + 12H_2O(g) + 6ZnO(s)$ $+ Al_2O_3(s)$	1
5	$2Ag_2O(s)$	$\Rightarrow$	$1O_2(g) + 4\ Ag(s)$	0.5
6	$4KFe_3(SO_4)$	$\Rightarrow$	$8SO_2(g) + 7O_2(g) + 12H_2O(g) +$ $2K_2O(s) + 12FeO(s)$	1
7	$4NaFe_3(SO_4)$	$\Rightarrow$	$2Na_20(e) + 8SO_2(g) + 7O_2(g) +$ $12H_2O(g) + 12FeO(sl)$	1
8	$1Fe_3(AsO_4)$	$\Rightarrow$	$1As_2O_5(s) + 3FeO(s)$	1
9	$2CaSO_6H_4(s)$	$\Rightarrow$	$2CaO(s) + 2SO_2(g) + O_2(g) + 4H_2O(g)$	1
10	$2CaSO_4(s)$	$\Rightarrow$	$2CaO(s) + 1O_2(g) + 2SO_2(g)$	1
11	Ca_3As_2O	$\Rightarrow$	$3CaO(s) + 1As_2O_3(s)$	1
12	$MgCO_3(s)$	$\Rightarrow$	$1MgO(s) + 1CO_2(g)$	1
13	$2ZnSO_4(s)$	$\Rightarrow$	$2SO_2(g) + 1O_2(g) + 2ZnO(s)$	1
14	$2CuFeO_2(s)$	$\Rightarrow$	$1Cu_2O(s) + 1Fe_2O_3(s)$	1
15	$4CuS(s)$	$\Rightarrow$	$2Cu_2S(s) + 1S_2(g)$	1
16	$4CuFeS_2(s)$	$\Rightarrow$	$2Cu_2S(s) + 4FeS(s) + 1S_2(g)$	1
17	$4Cu_5FeS_4(s)$	$\Rightarrow$	$10Cu_2S(s) + 4FeS(s) + 1S_2(g)$	1

No.	Reaction			Extent
18	$2Cu_3AsS_4(s)$	$\Rightarrow$	$3Cu_2S(s) + 1As_2S_3(s) + 1S_2(g)$	1
19	$1CuSO_4.5H_2O(s)$	$\Rightarrow$	$1CuSO_4(s) + 5H_2O(g)$	1
20	$4CuSO_4(s)$	$\Rightarrow$	$4SO_2(g) + 3O_2(g) + 2Cu_2O(s)$	1
21	$2FeS_2(s)$	$\Rightarrow$	$2FeS(s) + 1S_2(g)$	1
22	$1Fe_2As_4O_{12}$ (s)	$\Rightarrow$	$2As_2O_5(s) + 2FeO(w)(s)$	1
23	$2FeAsO_4(s)$	$\Rightarrow$	$As_2O_5(s) + 1Fe_2O_3(s)$	1
24	$1Fe_2(SO_4)_3$	$\Rightarrow$	$3SO_2(g) + 2O_2(g) + 2FeO(w)(s)$	1
25	$2FeSO_4(s)$	$\Rightarrow$	$1O_2(g) + 2SO_2(g) + 2FeO(w)(s)$	1
26	$4Cu(s) + 1O_2(g)$	$\Rightarrow$	$2Cu_2O(s)$	1
27	$1Cu_2O(s) + 1FeS(T)(s)$	$\Rightarrow$	$1Cu_2S(s) + 1FeO$ (sl)	0.896
28	$1Cu_2O(e) + FeS(T)(s)$	$\Rightarrow$	$1Cu_2S(s) + 1FeO$ (sl)	1
29	$2Na_3AsO_3$ (s)	$\Rightarrow$	$1As_2O_3(s) + 3Na_2O(s)$	1
30	$1Bi_2O_3(s)$	$\Rightarrow$	$1Bi_2O_3(e)$	0.995
31	$1Sb_2O_3(s)$	$\Rightarrow$	$1Sb_2O_3(e)$	0.995
32	1Ag (s)	$\Rightarrow$	1Ag (m)	0.995
33	1Au (s)	$\Rightarrow$	1Au (m)	0.995
34	1Mo(s)	$\Rightarrow$	1Mo(m)	0.995
35	1PbS(G)(s)	$\Rightarrow$	1PbS(m)	0.995
36	1PbO(L)(s)	$\Rightarrow$	1PbO(e)	0.995
37	$1PbSO_4(A)(s)$	$\Rightarrow$	$1PbSO_4(m)$	0.995
38	$1Na_2O(s)$	$\Rightarrow$	$1Na_2O_9(e)$	0.995
39	$1CaSiO_3(s)$	$\Rightarrow$	$1CaSiO_3(e)$	0.995
40	$CaAl_2SiO_2O_3(s)$	$\Rightarrow$	$CaAl_2Si_2O_3$ (e)	0.995
41	$1Al_2O_3(s)$	$\Rightarrow$	$1Al_2O_3(sl)$	0.995
42	$1Al_2SiO_5(s)$	$\Rightarrow$	$1Al_2SiO_5(e)$	0.995
43	$1Ca_2Fe_2O_5(s)$	$\Rightarrow$	$1Ca_2Fe_2O_5(e)$	0.995
44	$1MgSiO_2(s)$	$\Rightarrow$	$1MgSiO_3(sl)$	0.995
45	$1Na_2O(s)$	$\Rightarrow$	$1Na_2O(e)$	0.995
46	$1Na_2SiO_3(s)$	$\Rightarrow$	$1Na_2SiO_3(e)$	0.995
47	$1Cu_2O(s)$	$\Rightarrow$	$1Cu_2O(e)$	0.995
48	1FeO(s)	$\Rightarrow$	1FeO (de)	0.995

No.	Reaction			Extent
49	$1Fe_3O_4(s)$	⇒	$1Fe_3O_4$ (de)	0.995
50	$1Fe_2SiO_4(s)$	⇒	$1Fe_2SiO_4(e)$	0.995
51	$1As_2O_3(s)$	⇒	$1As_2O_3(e)$	0.995
52	$1As_2O_3(s)$	⇒	$1As_2O_3(e)$	0.995
53	$1As_2O_5(s)$	⇒	$1As_2O_5(e)$	0.995
54	$1K_2O(s)$	⇒	$1K_2O(e)$	1
55	$1ZnS(s)$	⇒	$1ZnS(s)(m)$	1
56	$1ZnO(s)$	⇒	$1ZnO(sl)$	0.995
57	$1TiO_2(s)$	⇒	$1TiO_2$ (m)	0.995
58	$1CaO$ (s) + $1SiO_2(s)$	⇒	$1CaSi_2O_3(e)$	0.995
59	$1Al_2O_3(s) + 1CaSiO_3(e)$	⇒	$1SiO_2(s) + 1CaAl_2O_4(s)$	0.995
60	$1MgO(P)(s) + 1SiO_2(s)$	⇒	$1MgSiO_3(sl)$	0.995
61	$1Na_2O(e) + 1SiO_2(s)$	⇒	$1Na_2SiO_3(e)$	0.995
62	$1CuO(s)$	⇒	$1CuO$ (e)	0.995
63	$3CuO(s) + 1FeS(T)(s)$	⇒	$3Cu(m) + 1FeO(sl)$ $+ 1SO_2(g)$	1
64	$1PbSO_4(m) + 1PbS(m)$	⇒	$2Pb(m) + 2SO_2(g)$	1
65	$2PbS(m) + 3O_2(g)$	⇒	$2SO_2(g) + 2PbO(e)$	0.995
66	$1MoS_2(s) + 3O_2(g)$	⇒	$1MoO_2(s) + 2SO_2(g)$	0.995
67	$2MoO_2(s) + 1O_2(g)$	⇒	$2MoO_3(g)$	1
68	$2Sb_2S_3(s) + 9O_2(g)$	⇒	$6SO_2(g) + 2Sb_2O_3(e)$	0.995
69	$4Sb(s) + 3O_2(g)$	⇒	$2Sb_2O_3(m)$	0.995
70	$1Ag_2S(s) + 1O_2(g)$	⇒	$2Ag(m) + 1SO_2(g)$	0.995
71	$2Pb(s) + 1O_2(g)$	⇒	$2PbO(e)$	0.995
72	$2Bi_2S_3(s) + 9O_2(g)$	⇒	$6SO_2(g) + 2Bi_2O_3(e)$	0.995
73	$2Zn(s) + 1O_2(g)$	⇒	$2ZnO$ (de)	0.995
74	$4Cu(s) + 1O_2(g)$	⇒	$2Cu_2O(e)$	0.995
75	$4As(s) + 3O_2(g)$	⇒	$2Bi(g) + 3SO_2(g)$	0.995
76	$1Bi_2S_3(s) + 3O2(g)$	⇒	$2Bi(g) + 3SO_2(g)$	1
77	$1C(s) + 1O_2(g)$	⇒	$1CO_2(g)$	1
78	$1S_2(g) + 2O_2(g)$	⇒	$2SO_2(g)$	1

No.	Reaction			Extent
79	$1S_2(g) + 2O_2(g)$	$\Rightarrow$	$2SO_2(g)$	1
80	$1Cu_2S(s)$	$\Rightarrow$	$1Cu_2S(m)$	0.995
81	$1FeS(s)$	$\Rightarrow$	$1FeS(m)$	0.995
82	$3FeS(m) + 5O_2(g)$	$\Rightarrow$	$1Fe_3O_4(m) + 3SO_2(g)$	0.010
83	$2As_2S_3(m) + 9O_2(g)$	$\Rightarrow$	$6SO_2(g) + 2As_2O_3(e)$	0.796
84	$2As_2O_3(e)$	$\Rightarrow$	$1As_4O_6(g)$	0.850
85	$2ZnS(s)(m\ ) + 3O_2(g)$	$\Rightarrow$	$2SO_2(g) + 2ZnO(g)$	0.924
86	$1ZnO(sl)$	$\Rightarrow$	$1ZnO(g)$	1
87	$2ZnO(g)$	$\Rightarrow$	$2ZnO(sl)$	0.322
88	$2FeS(m) + 3O_2(g)$	$\Rightarrow$	$2FeO(de) + 2SO_2(g)$	0.914
89	$1Fe_2O_3(s) + 1FeO(sl)$	$\Rightarrow$	$1Fe_3O_4(sl)$	1
90	$1SiO_2(s)$	$\Rightarrow$	$1SiO_2(sl)$	0.995
91	$2FeO(sl) + 1SiO_2(sl)$	$\Rightarrow$	$1Fe_2SiO_4(e)$	0.770
92	$6FeO(sl) + 1O_2(g)$	$\Rightarrow$	$2Fe_3O_4(sl)$	1
93	$2CuS(s) + 3O_2(g)$	$\Rightarrow$	$2Cu_2O(s) + 2SO_2(g)$	1
94	$3FeS(s) + 5O_2(g)$	$\Rightarrow$	$1Fe_3O_4(s) + 3SO_2(g)$	1
95	$2Ag_2S(s) + 3O_2(g)$	$\Rightarrow$	$2Ag_2O(s) + 2SO_2(g)$	1
96	$2As_2S_3(s) + 9O_2(g)$	$\Rightarrow$	$2As_2O_3(s) + 6SO_2(g)$	1
97	$2Sb_2S_3(s)+9O_2(g)$	$\Rightarrow$	$2Sb_2O_3(s) + 6SO_2(g)$	1
98	$2ZnS(s)(m) + 3O_2(g)$	$\Rightarrow$	$2ZnO(s) + 2SO_2(g)$	1
99	$1Mo(m)$	$\Rightarrow$	$1Mo(e)$	1

For the calculation, METSIM follows the order of reactions from number 1 to 99 and the rate of reactions is fixed by the extent of the reaction. It is noted that in this study, the extent of all reactions except the reaction no. 88 and 91 is specified following the technical data obtained form other smelters that uses the same Teniente converter technology. The extent of the reaction no. 88 and 91 are estimated from actual plant data.

VITA

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