Helmholtz Institute Freiberg for Resource Technology

Dynamic model of a TSL furnace, developed with SimuSage^{TM} software

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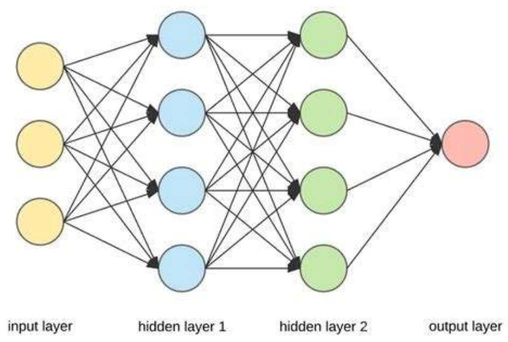
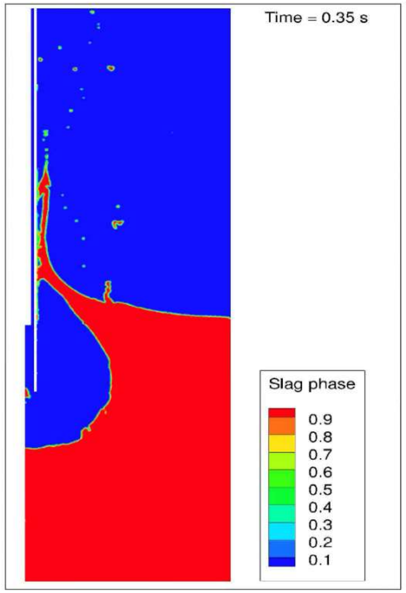
Dynamic Modeling Methods



Neural Networks coupled with Autoregressive model

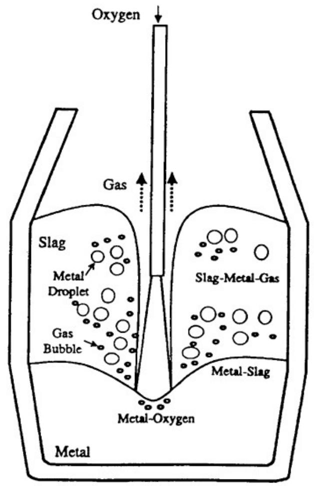
Georgalli et al. (2002) Minerals Engineering:
Ni-Cu TSL



CFD coupled with reaction kinetics

Huda et al. (2012) MMTB:
Zinc fuming in TSL

Obiso et al. (2019) MMTB:
TSL CFD, viscosity & surface tension in slag



Compartamentalised model, coupled with kinetic rate equations

Rout et al. (2018) MMTB:
Basic Oxygen Steelmaking Process

Connected Local Equilibria Method (Compartamentalised model)

Logic

- Furnace consists of well-mixed zones.
- Zones are in internal equilibrium.
- Mass transfer controlled reactions.
- Interface areas and reaction mechanisms are not described

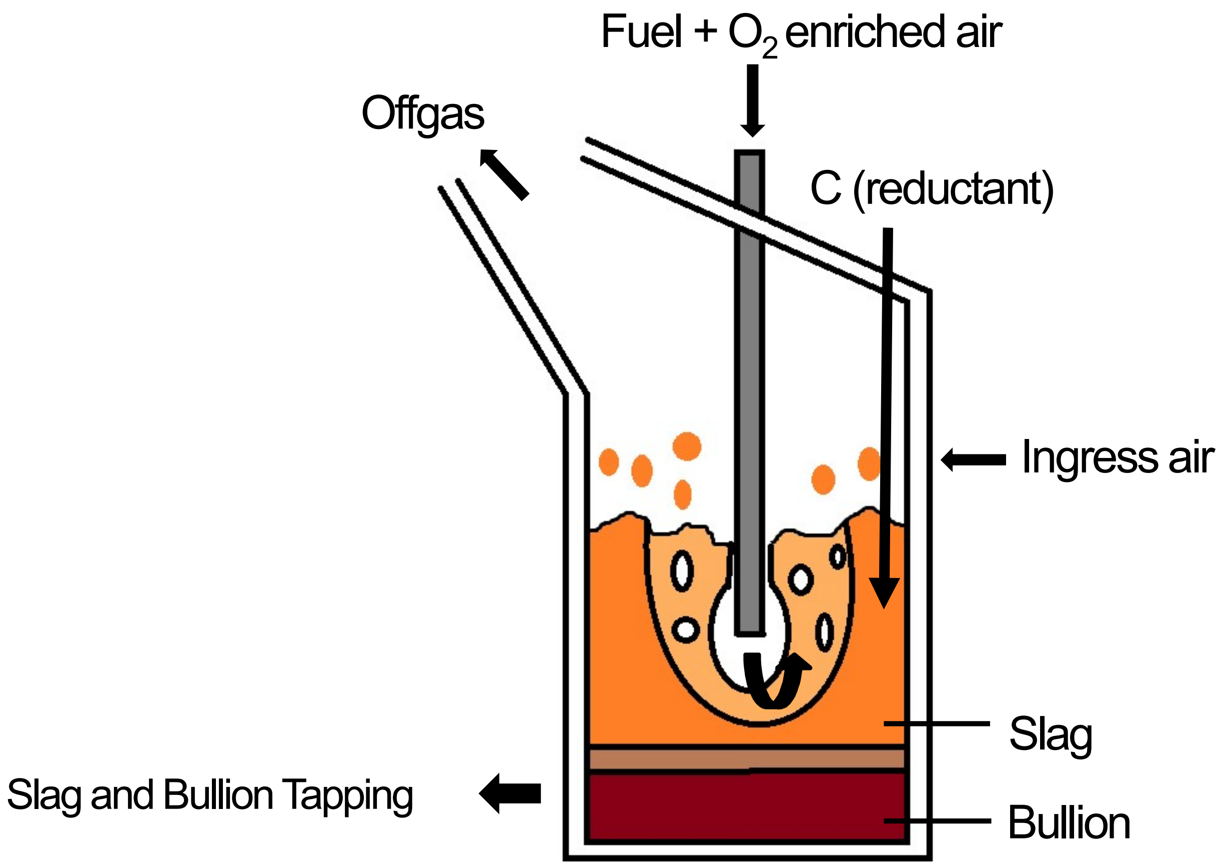
FactSage

- Thermodynamic database.
- Pure components and optimised solutions.
- Calculates equilibrium according to composition and temperature.

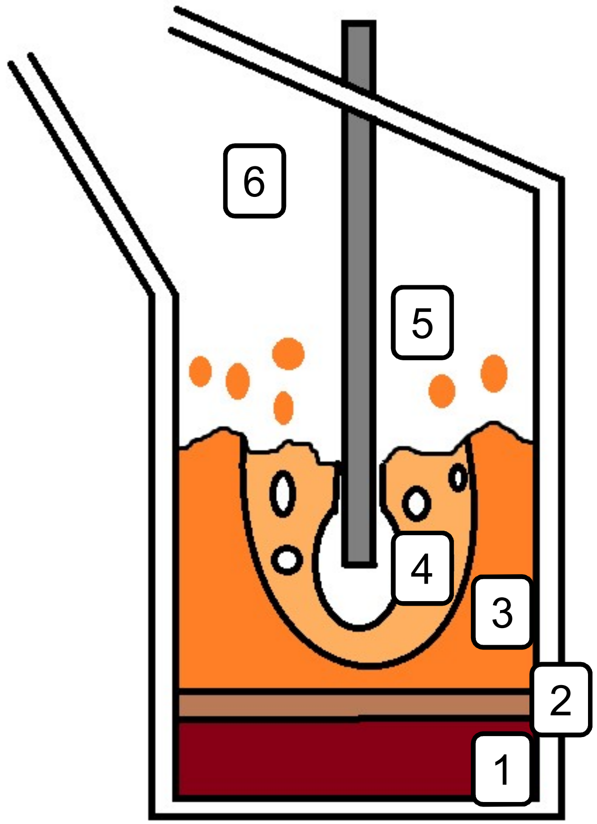
SimuSage

- Flowsheet with connected Equilibrium Zones.
- Mass transfer between zones can be specified.

Top Submerged Lance Furnace (TSL)

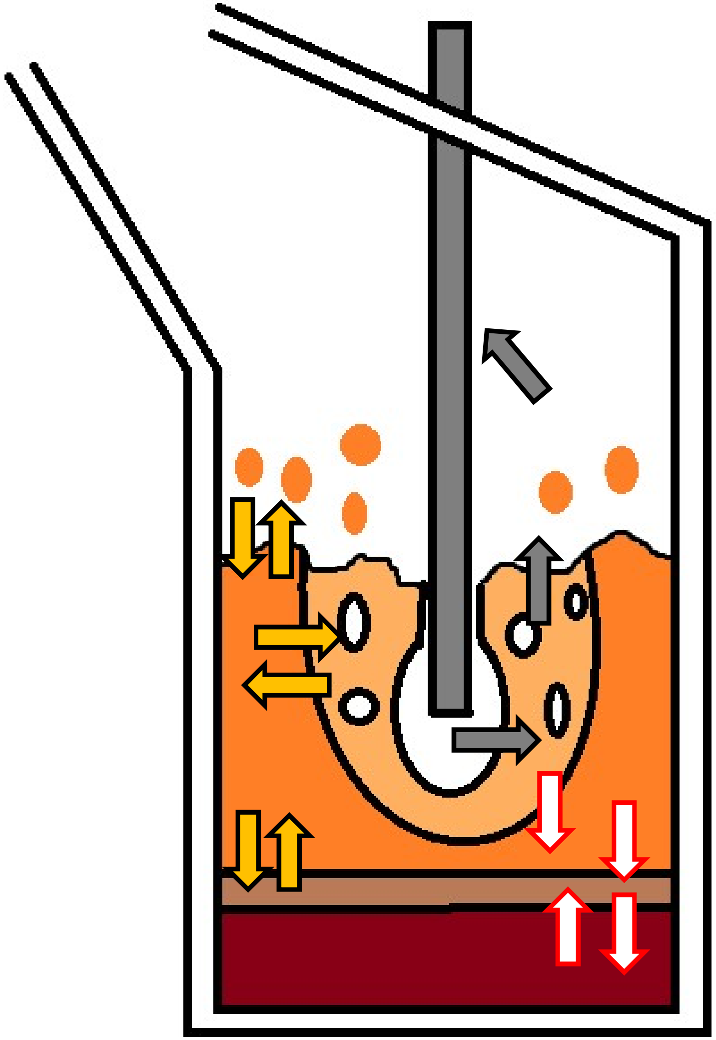


Reactor Zones

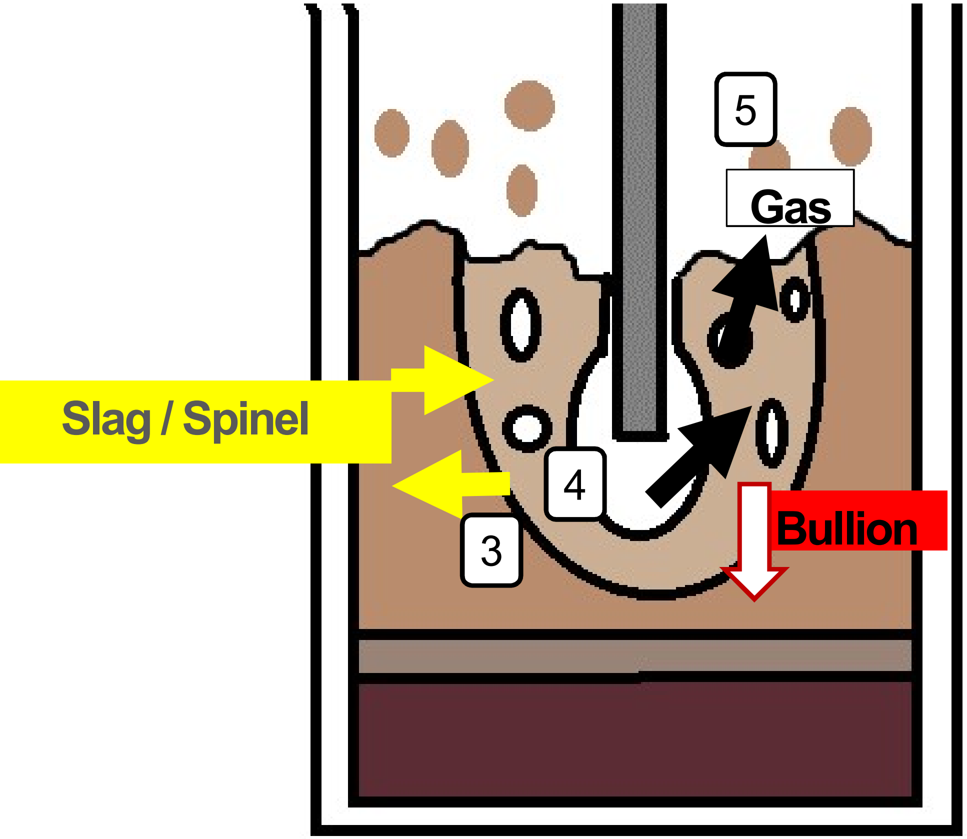


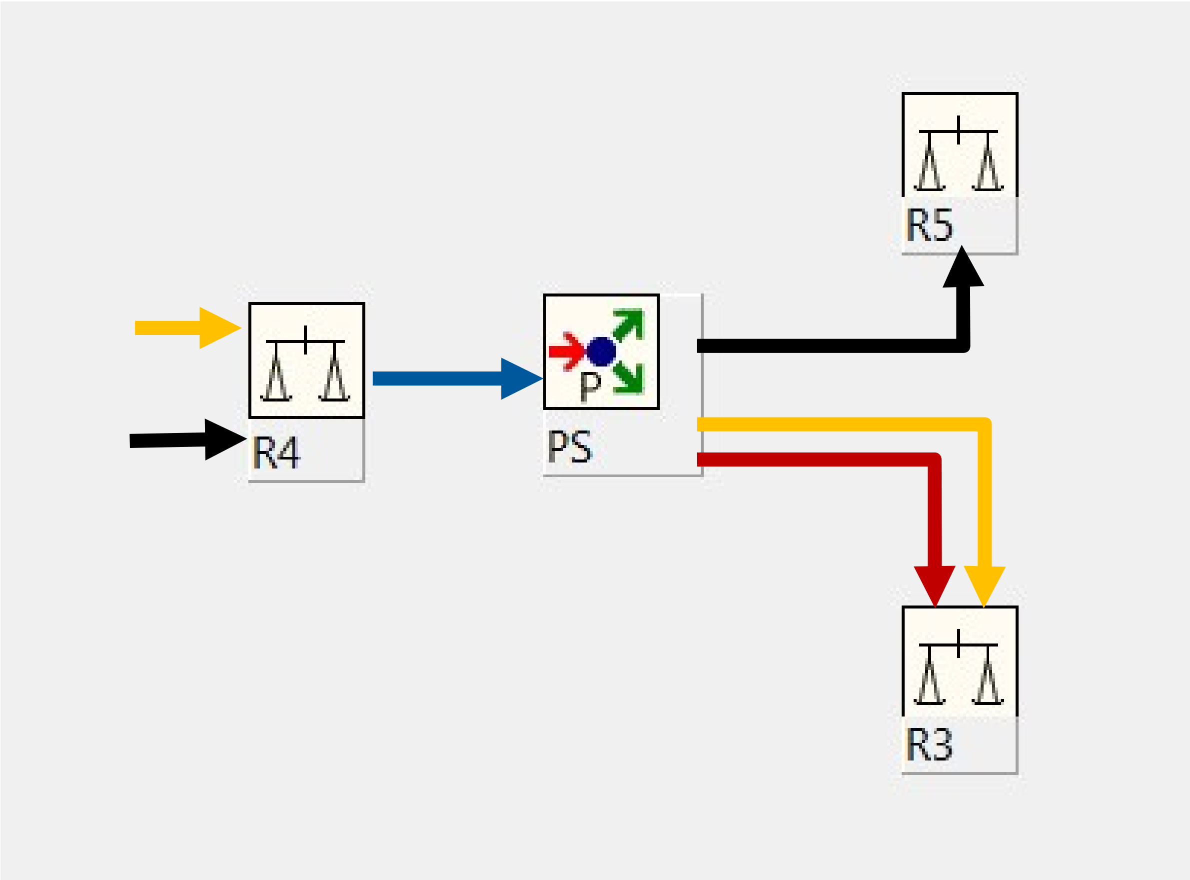
6. Freeboard
5. Splash Zone
4. Bubble Zone
3. Slag
2. Slag/Bullion Contact
1. Bullion Zone

Reactor Zones

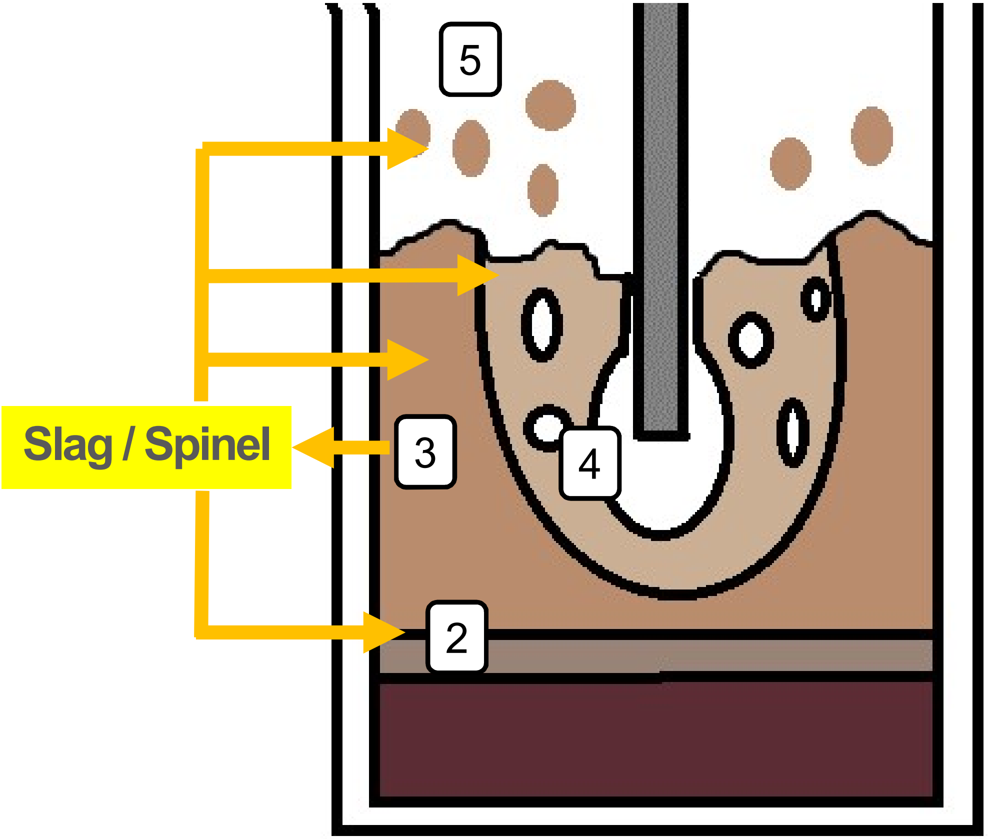


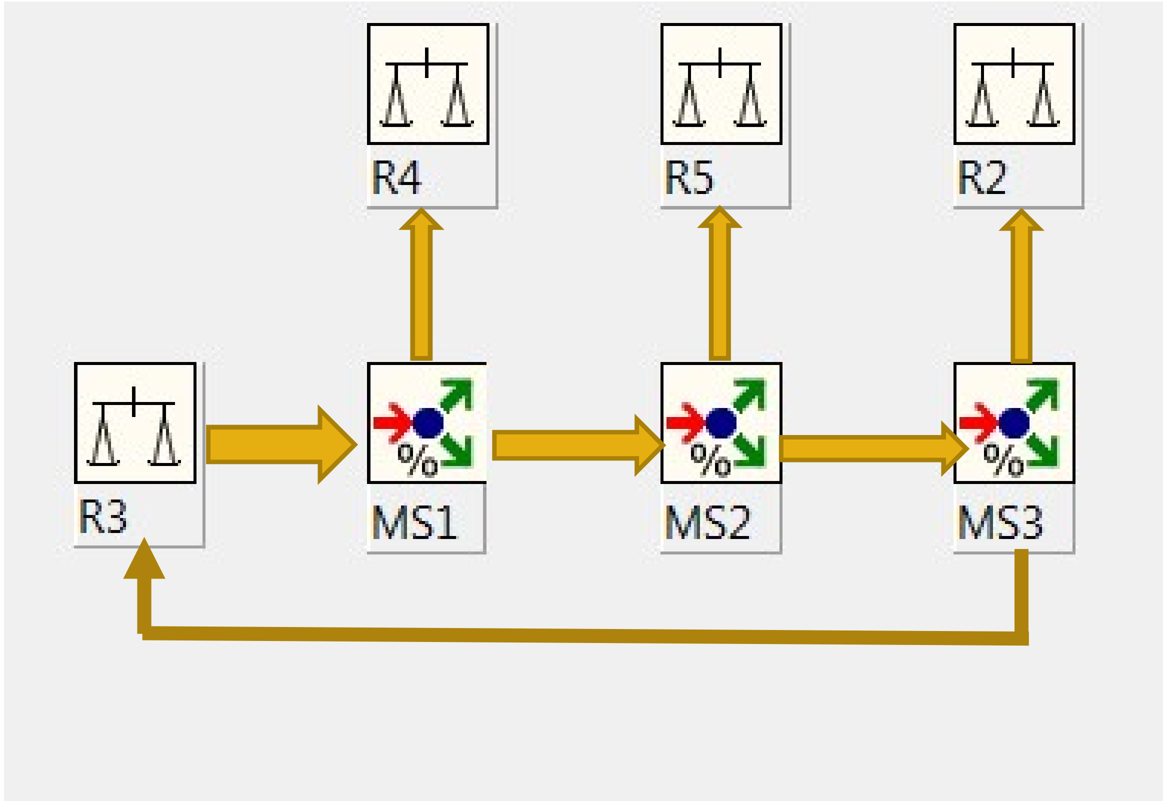
SimuSage: Phase Splitters



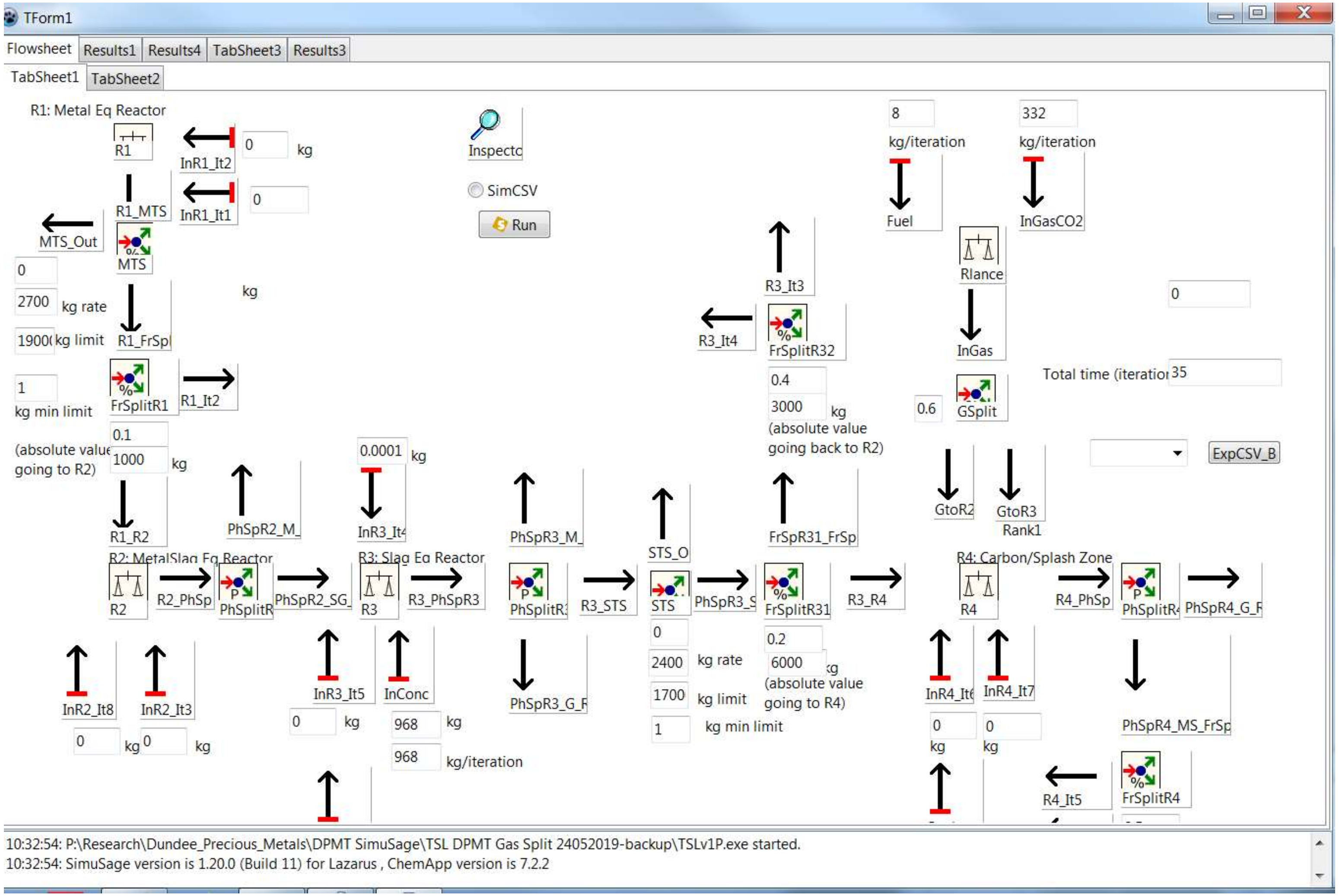


SimuSage: Mass Splitters



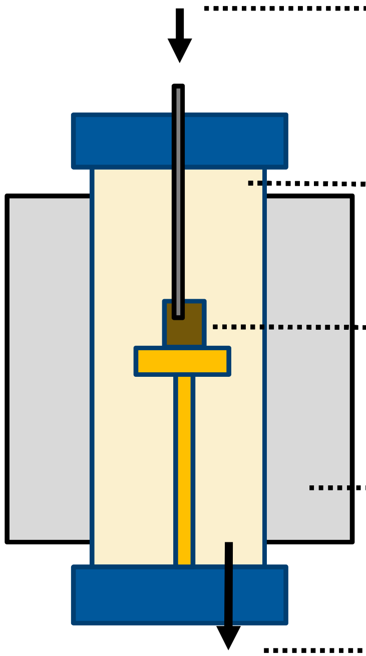


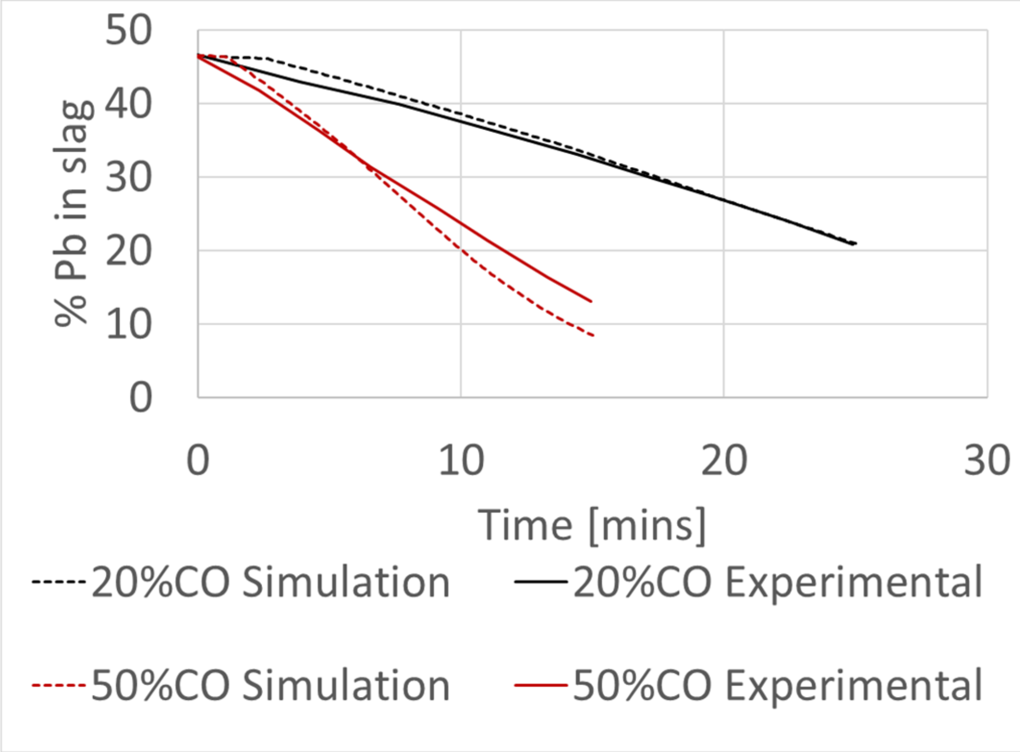
SimuSage Interface



PbO reduction example: comparison to literature

Reduction of PbO-FCS slag at 1220 °C

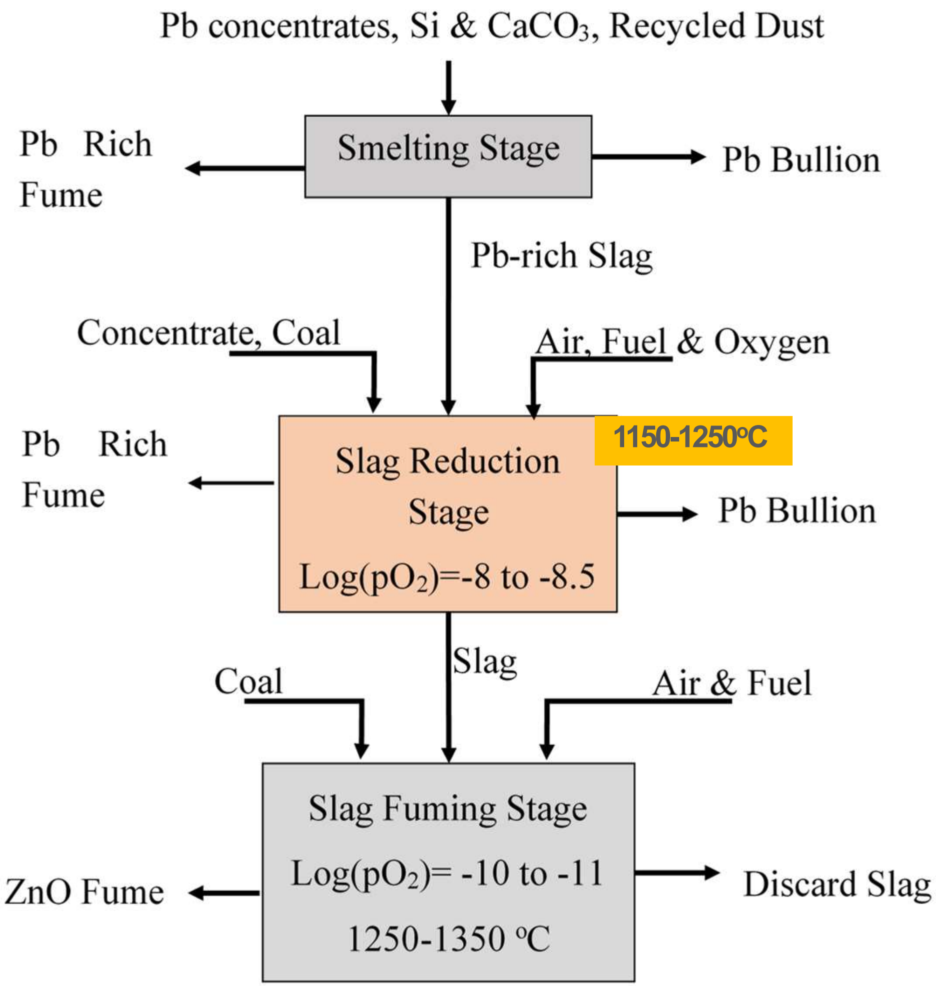




Experimental data from:
Jahanshahi & Wright (2017)

$\dot{m}$=k. X_{Pb}

PbO Reduction Example



$$2PbS(s) + 3O_2(g) = 2PbO + 2SO_2(g)$$
$$PbS(s) + O_2(g) = Pb(l) + SO_2(g)$$

$$PbO(l) + C(s) = Pb(l) + CO(g)$$
$$PbO(l) + CO(g) = Pb(l) + CO_2(g)$$

$$ZnO(l) + C(s) = Zn(g) + CO(g)$$
$$PbO(l) + C(s) = Pb(g) + CO(g)$$

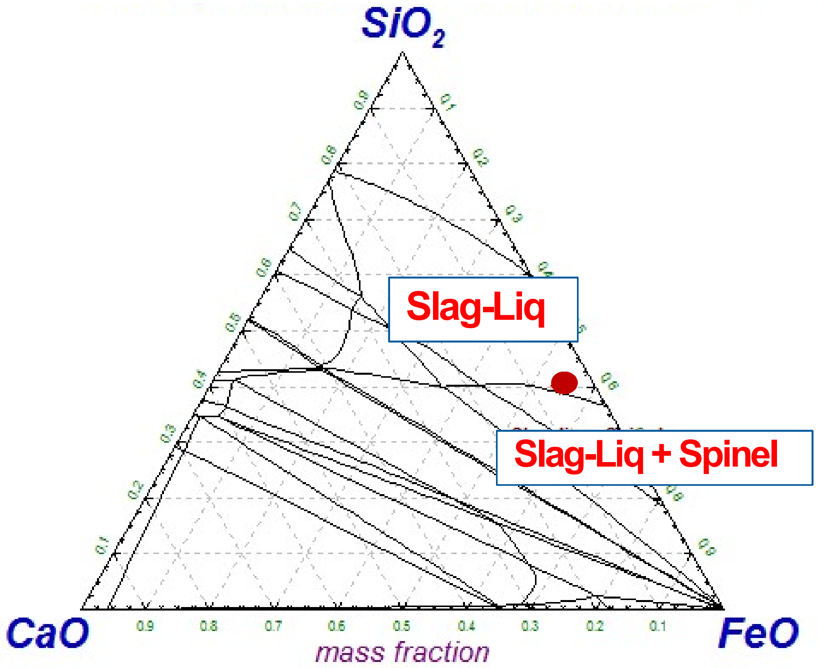
Gu et al. (2012)

PbO Reduction Slag Chemistry: Selection of databases and solutions

SiO2-FeO-CaO

ZnO = 9 %, PbO = 28 %, Log pO_2 = -8

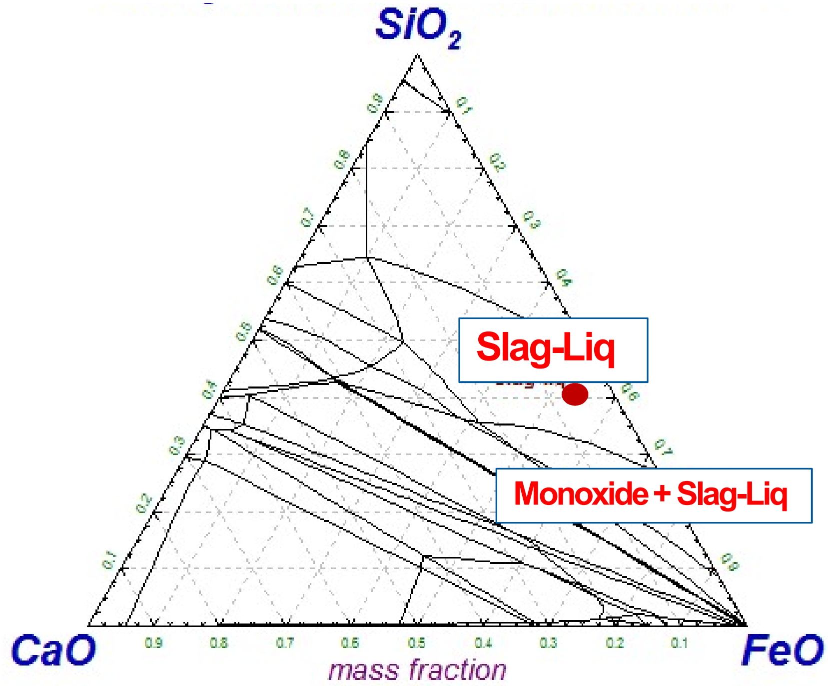
T = 1200 ^oC



SiO2-FeO-CaO

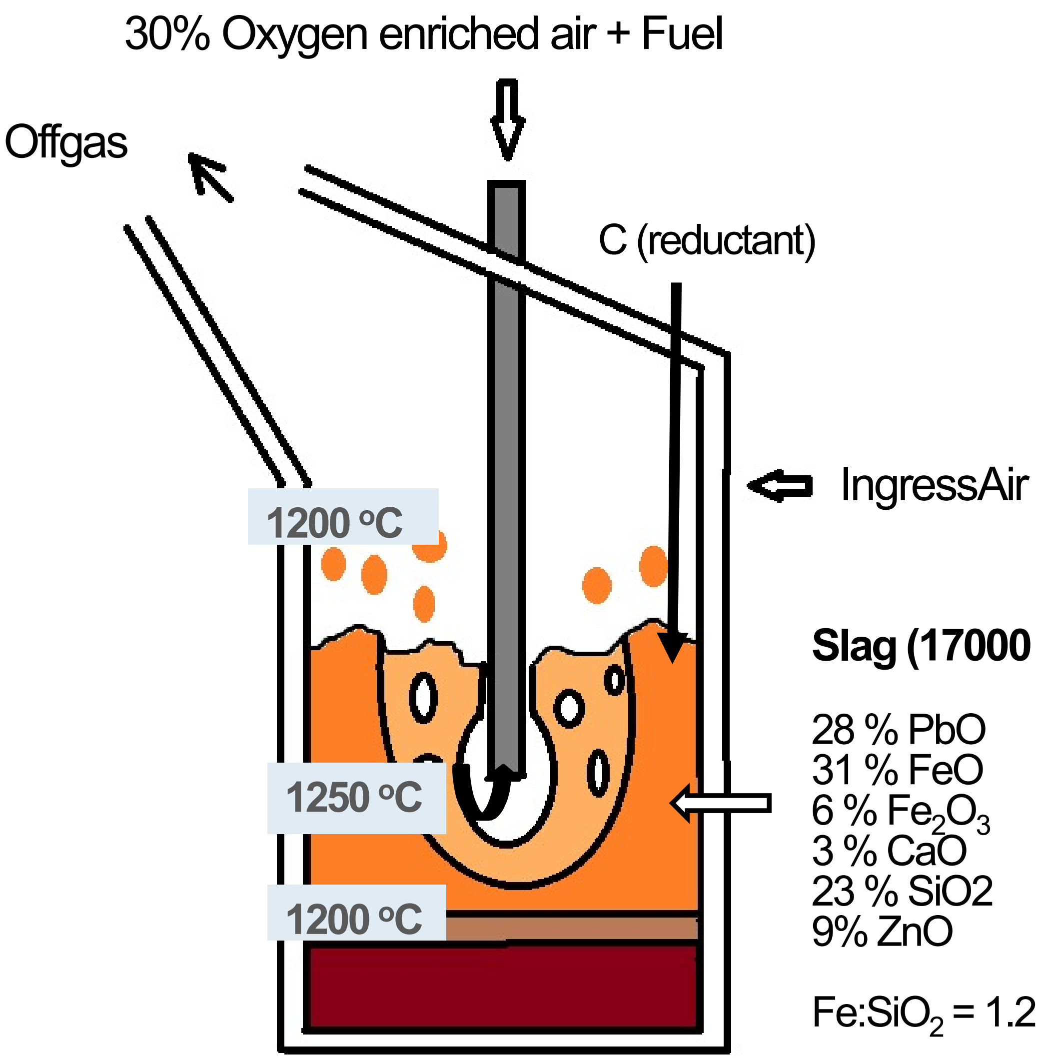
ZnO = 11 %, PbO = 5 %, Log pO_2 = -9

T = 1200 ^oC



FactSage Study: main phases to form will be Bullion, Slag and Spinel

PbO slag reduction: Industrial size

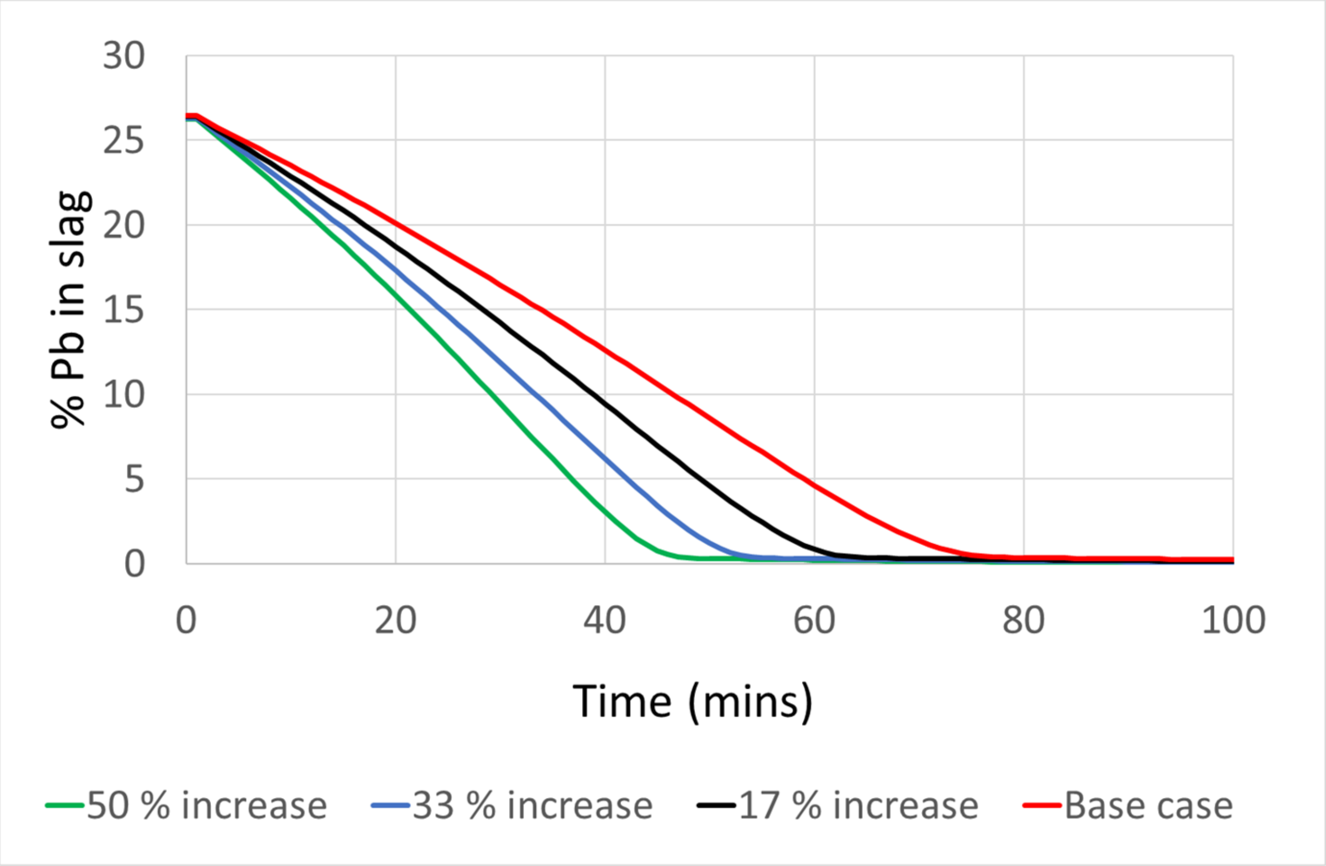


Slag (17000 kg)

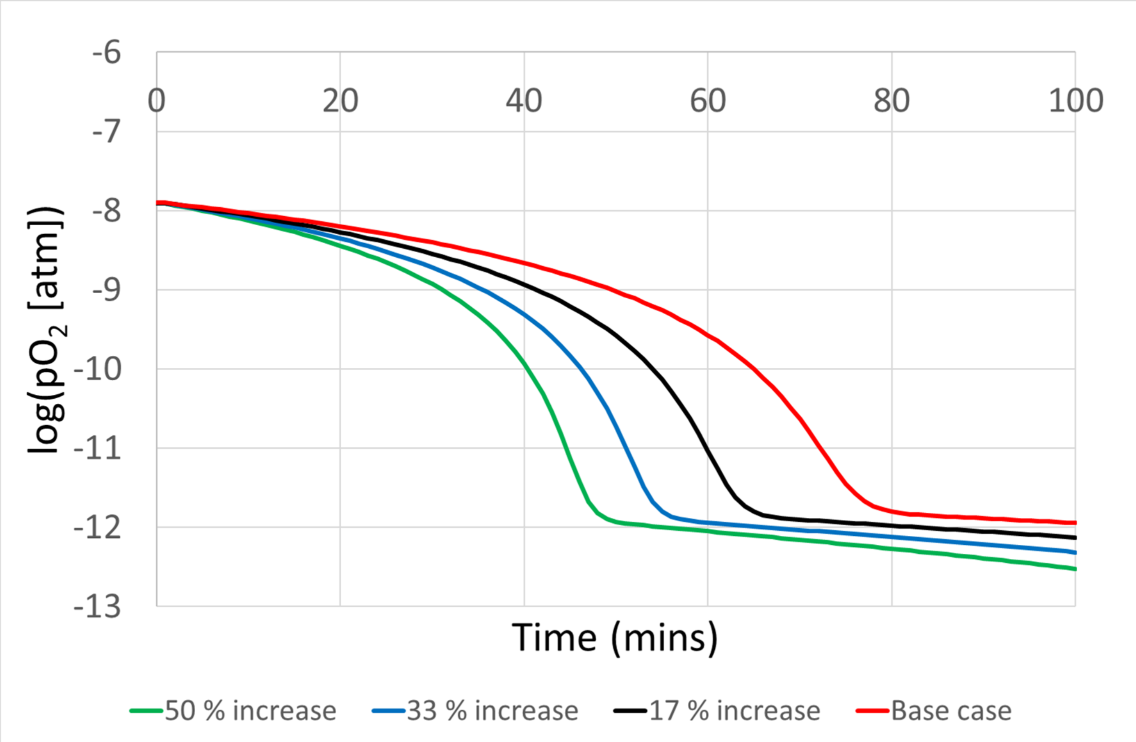
28 % PbO
31 % FeO
6 % Fe_2O_3
3 % CaO
23 % SiO2
9% ZnO

$Fe:SiO_2 = 1.2$

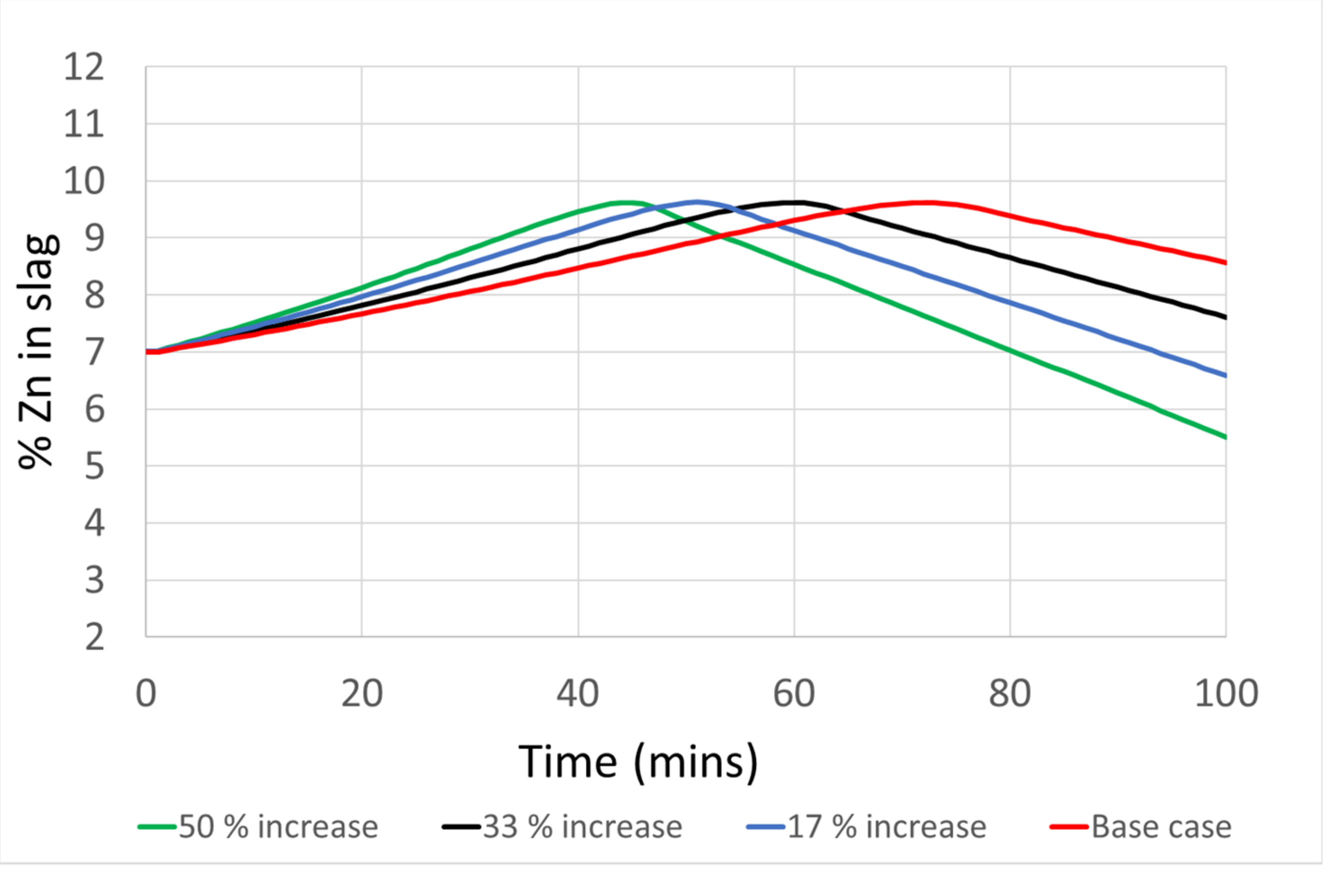
Effect of increased coal addition



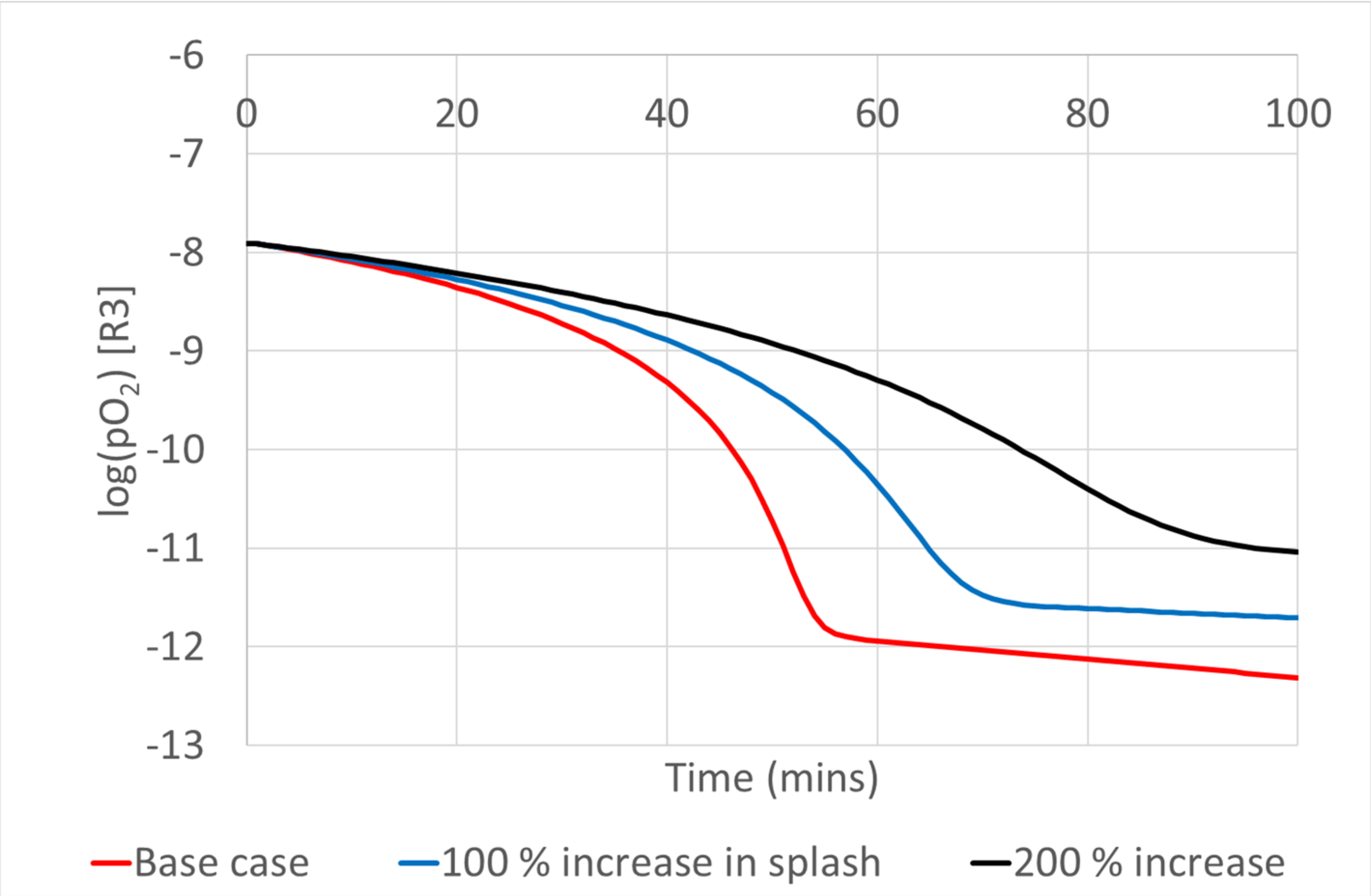
Effect of increased coal addition



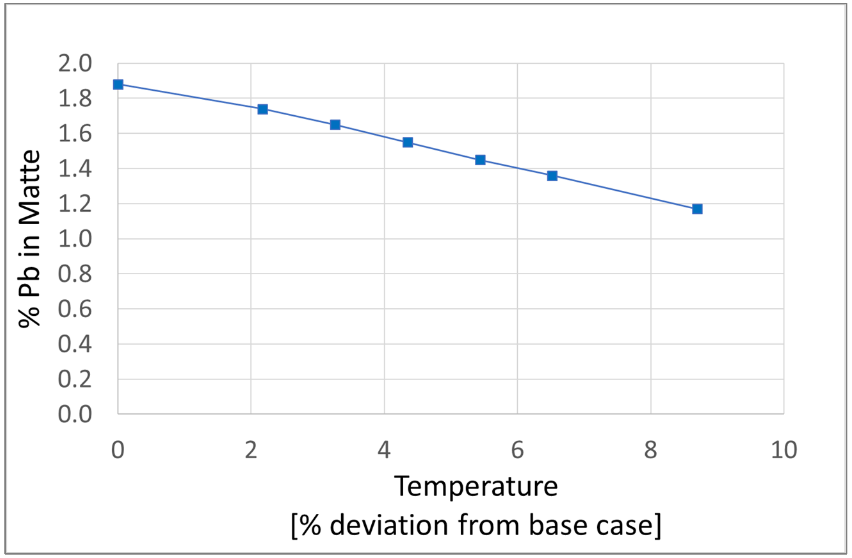
Effect of increased coal addition

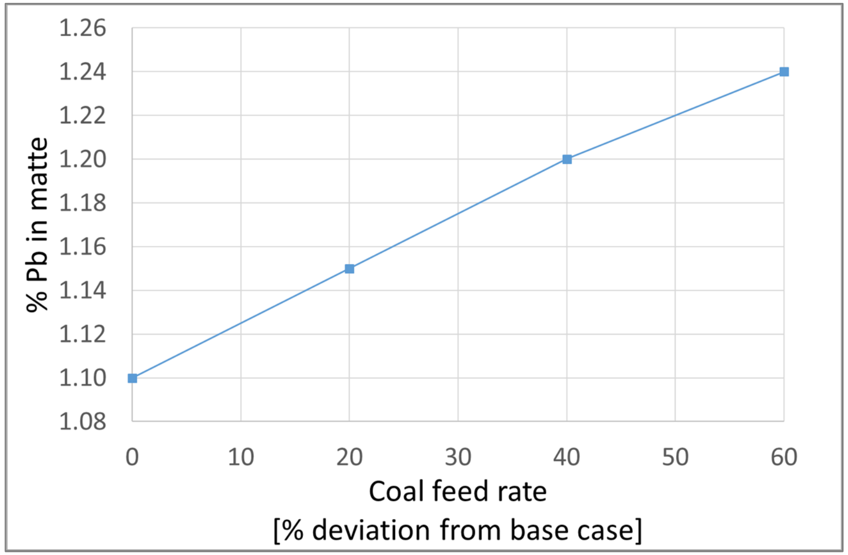


Effect of increased splash



Industrial Cu Matte TSL Smelting Application – Calibrated on site





Conclusions

- Model applied to predict trends and test parameters in PbO reduction process – can be adapted for other processes as shown for industrial copper matte smelting.
- Model can be extended to consider more elements, if thermodynamic data are available.
- Model accuracy depends on suitable choices for mass transfer parameters i.e. the flow of material between the different zones.

Outlook

- Accuracy improvement: better flow modelling, link to CFD.
- Accuracy improvement: better thermal profile, link to measurements at TUBAF.
- Model Thermal profile by using temperature calculation in SimuSage.
- Validation of model vs. experimental data or operational data.

References

Jahanshahi S, Wright S. Kinetics of Reduction of CaO-FeO x-MgO-PbO-SiO2 Slags by CO-CO2 Gas Mixtures. Metallurgical and Materials Transactions B. 2017 Aug 1;48(4):2057-66.

Georgalli GA, Eksteen JJ, Reuter MA. An integrated thermochemical-systems approach to the prediction of matte composition dynamics in an Ausmelt® nickel–copper matte converter. Minerals Engineering. 2002 Nov 1;15(11):909-17

Gu H, Song X, Lan X, Ross B, Ross A, Markus R. Design and commissioning of the Ausmelt TSL lead smelter at Yunnan Tin Company Limited. InInternational Smelting Technology Symposium: Incorporating the 6th Advances in Sulfide Smelting Symposium 2012 May 9 (pp. 11-21). The Minerals, Metals & Materials Society Orlando, Florida, USA

Huda N, Naser J, Brooks G, Reuter MA, Matusewicz RW. Computational fluid dynamic modeling of zinc slag fuming process in top-submerged lance smelting furnace. Metallurgical and Materials Transactions B. 2012 Feb 1;43(1):39-55

Rout BK, Brooks G, Rhamdhani MA, Li Z, Schrama FN, Sun J. Dynamic Model of Basic Oxygen Steelmaking Process Based on Multi-zone Reaction Kinetics: Model Derivation and Validation. Metallurgical and Materials Transactions B. 2018 Apr 1;49(2):537-57

Obiso D, Kriebitzscha S., Reuter MA, Meyer B. The importance of viscous and interfacial forces in the hydrodynamics of the Top-Submerged-Lance furnace. . Metallurgical and Materials Transactions B 2019 (in press)