Thermochemical Modelling in the BOFdePhos Project

K. Hack[1], P. Monheim[1], T. Jantzen[1], T.Kürten[1], S.Khadhraoui[2]

[1]GTT-Technologies, [2]SMS-Demag

RCCM/GTT User Meeting, Tokyo 2016

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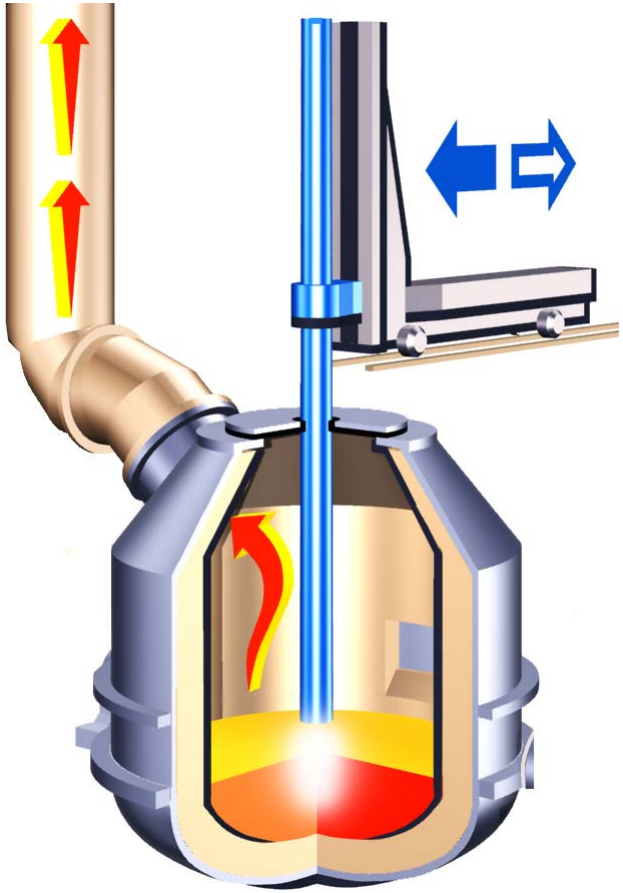
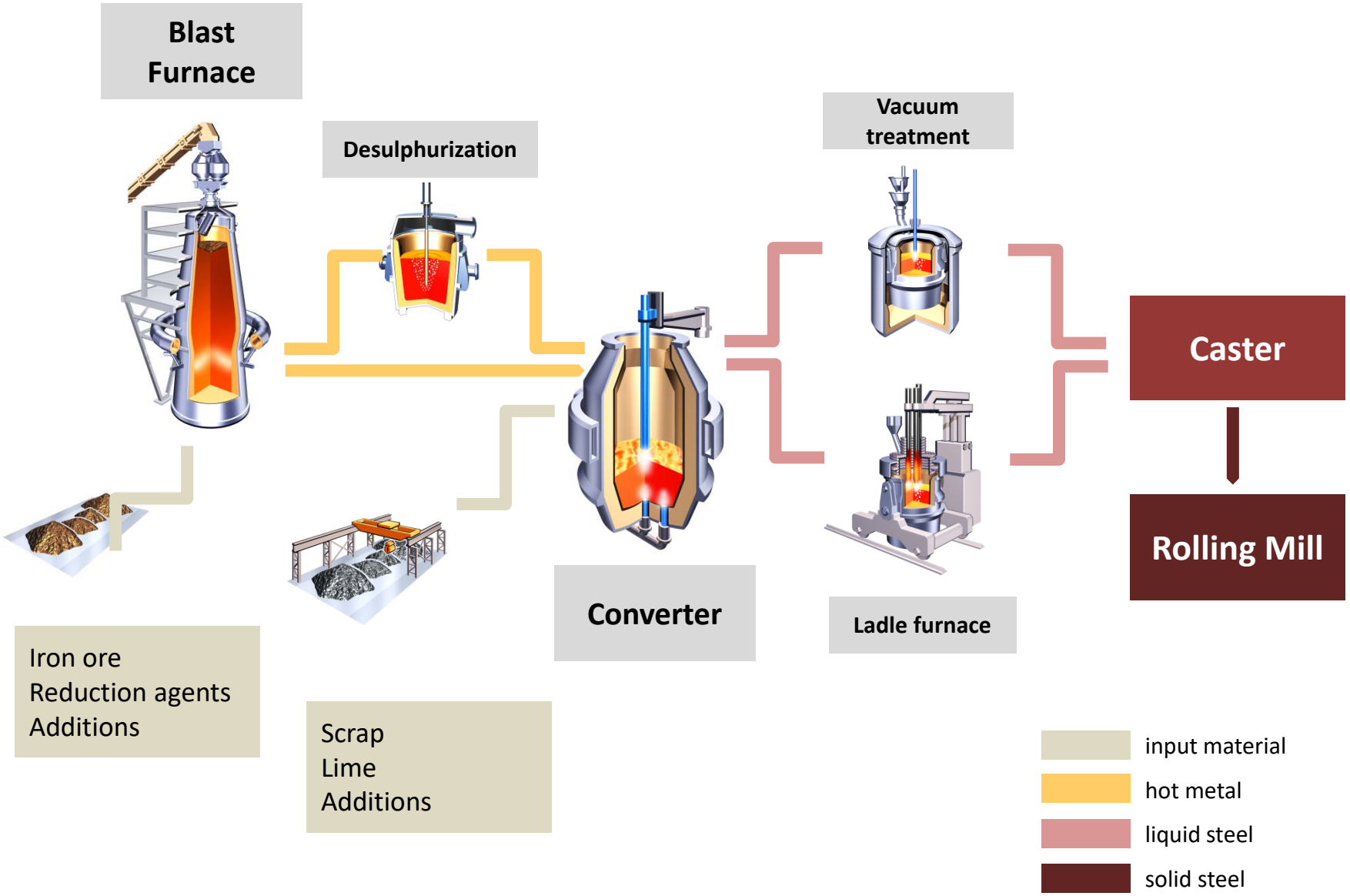
Titel



Steel Production :The Oxygen Steelmaking route



Introduction to BOF DePhos project

- BOF DePHOS: Dynamic on-line monitoring and end-point control of dephosphorisation in the BOF converter process
- Project period: 01.07.2014 – 31.12.2017
- Main Objective: Development of a comprehensive dynamic process models for the BOF process, including SimuSage based modelling
  - based on detailed studies of the thermodynamic and reaction kinetics fundamentals
  - determination of the end-point of the process with respect to phosphorus content and melt temperature with higher accuracy
  - to be used for online monitoring and process control
  - application of new sensors measuring the oxygen activity and height of the converter slag

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Project participants

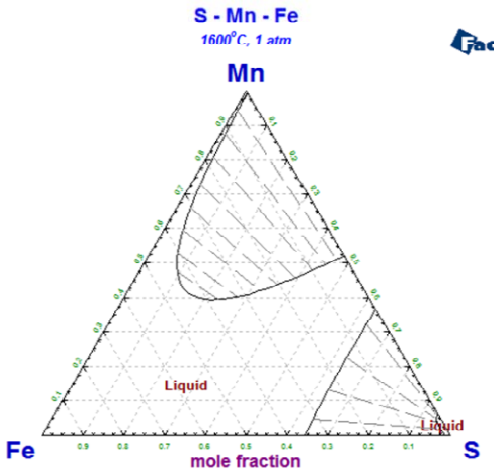
- VDEh-Betriebsforschungsinstitut (BFI)
  Private-sector institute for applied research and development in steel technology
- Tata Steel UK (Tata) Steelmaking company involved with its BOF plants at Port Talbot and Ijmuiden
- SMS Siemag AG (SMS) Supplier for steelmaking and processing plants
- Gesellschaft für Technische Thermochemie und –physik mbH (GTT)
  Supply and consulting with respect to thermochemical databases and related software
- Kungliga Tekniska Hoegskolan (KTH) Technical university with wide activities in metallurgical and materials processes
- Minkon GmbH (Minkon) Supplier for sampling technology and measuring sensors for metallurgical processes

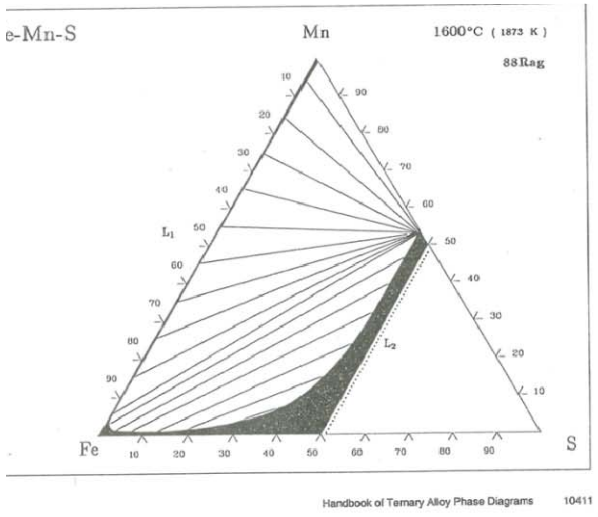
GTT involvement in BOFdePhos

- Main activities of GTT are:
  - generation of a self-consistent thermodynamic database
  - generation of stand-alone process model based on interlinked local equilibria (with SMS)
  - integration of new thermodynamic database into process model (with SMS)
  - integration of third party kinetic models, especially CaO-dissolution, into process model (with SMS and KTH)
  - making available sub-models (to BFI and SMS)

Generation of a self-consistent thermodynamic database

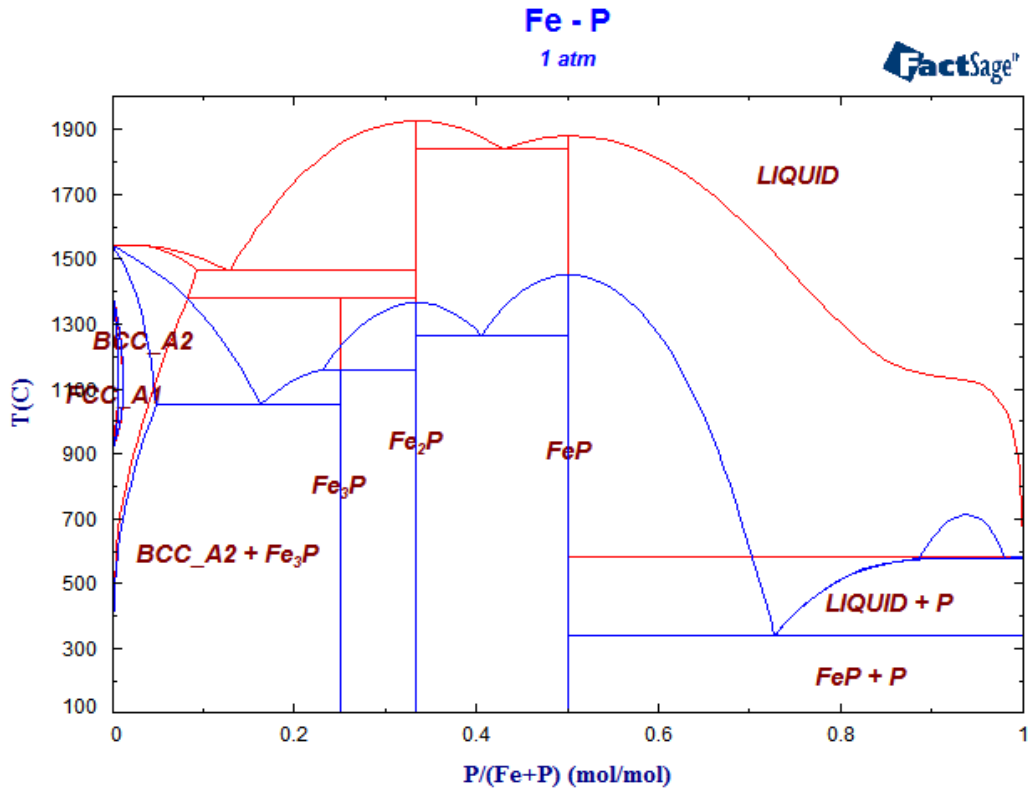
Data revision - Part 1





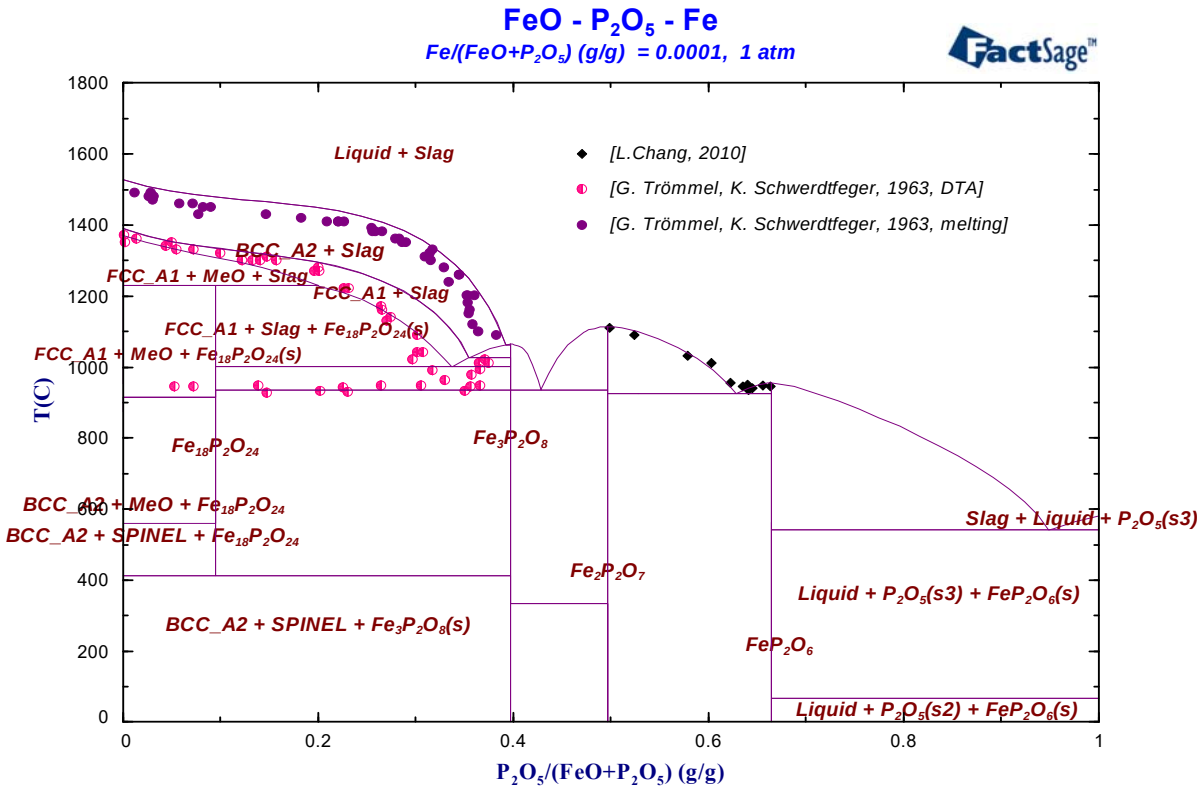
Generation of a self-consistent thermodynamic database

Data revision - Part 2



Generation of a self-consistent thermodynamic database

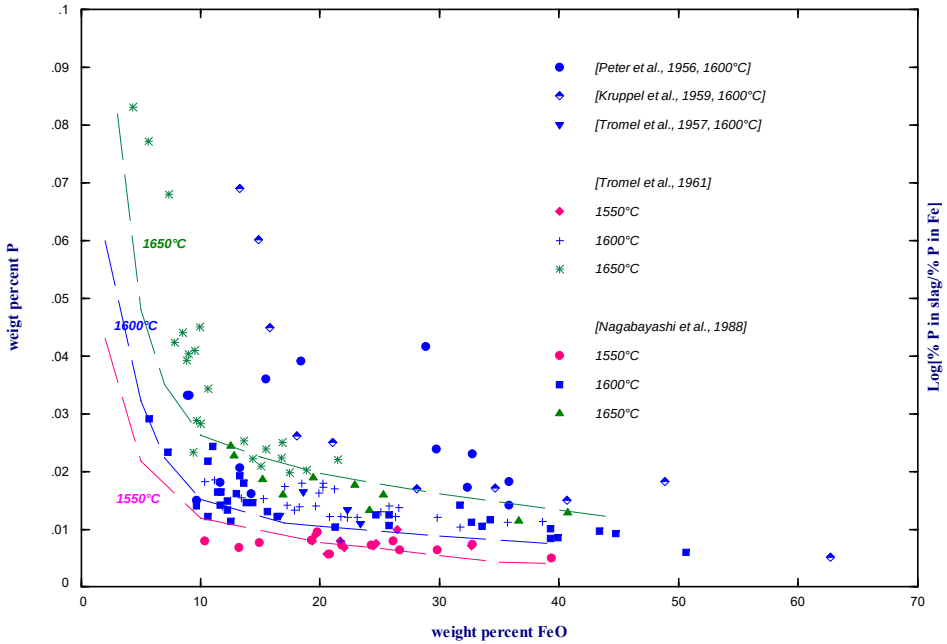
Data revision - Part 2



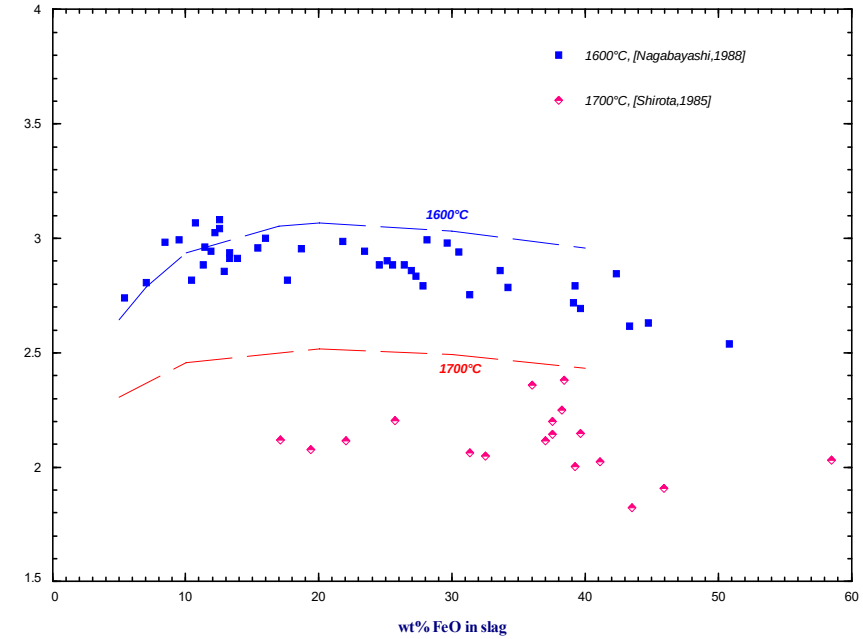
Generation of a self-consistent thermodynamic database

Data revision - Part 2

Relationship between [%P] in liquid Fe and (FeO) in slag



The L_p between molten iron and the slag along the CaO saturation.



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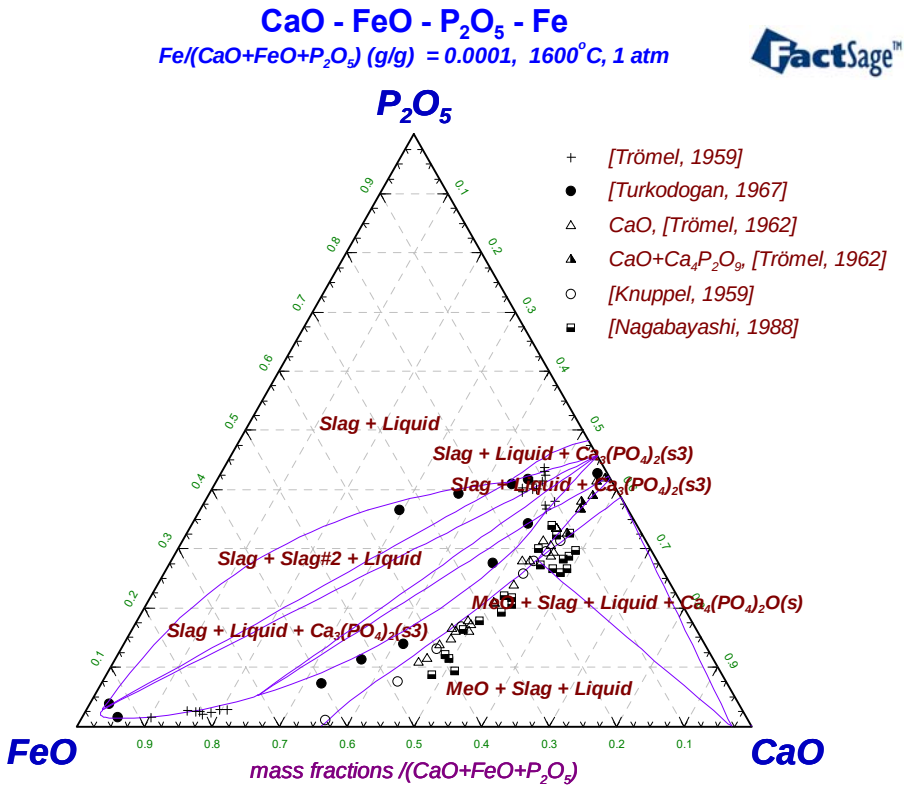
Generation of a self-consistent thermodynamic database

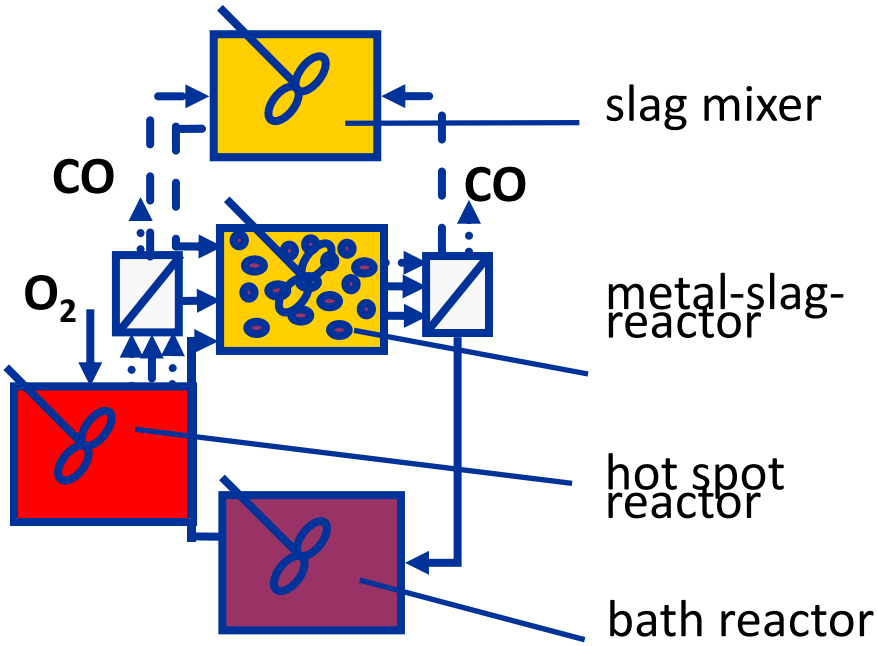
Data revision - Part 2

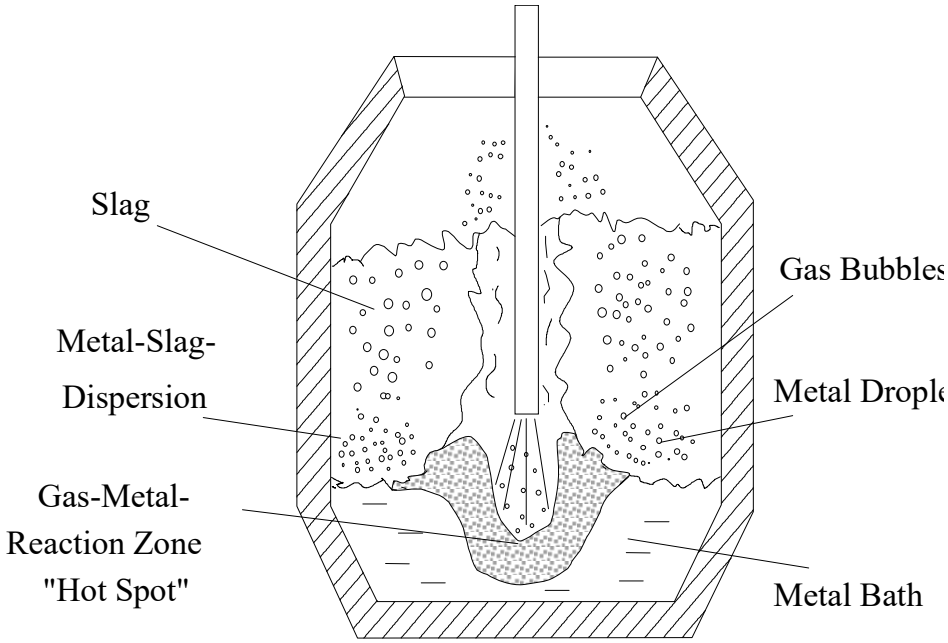


Generation of stand-alone process model

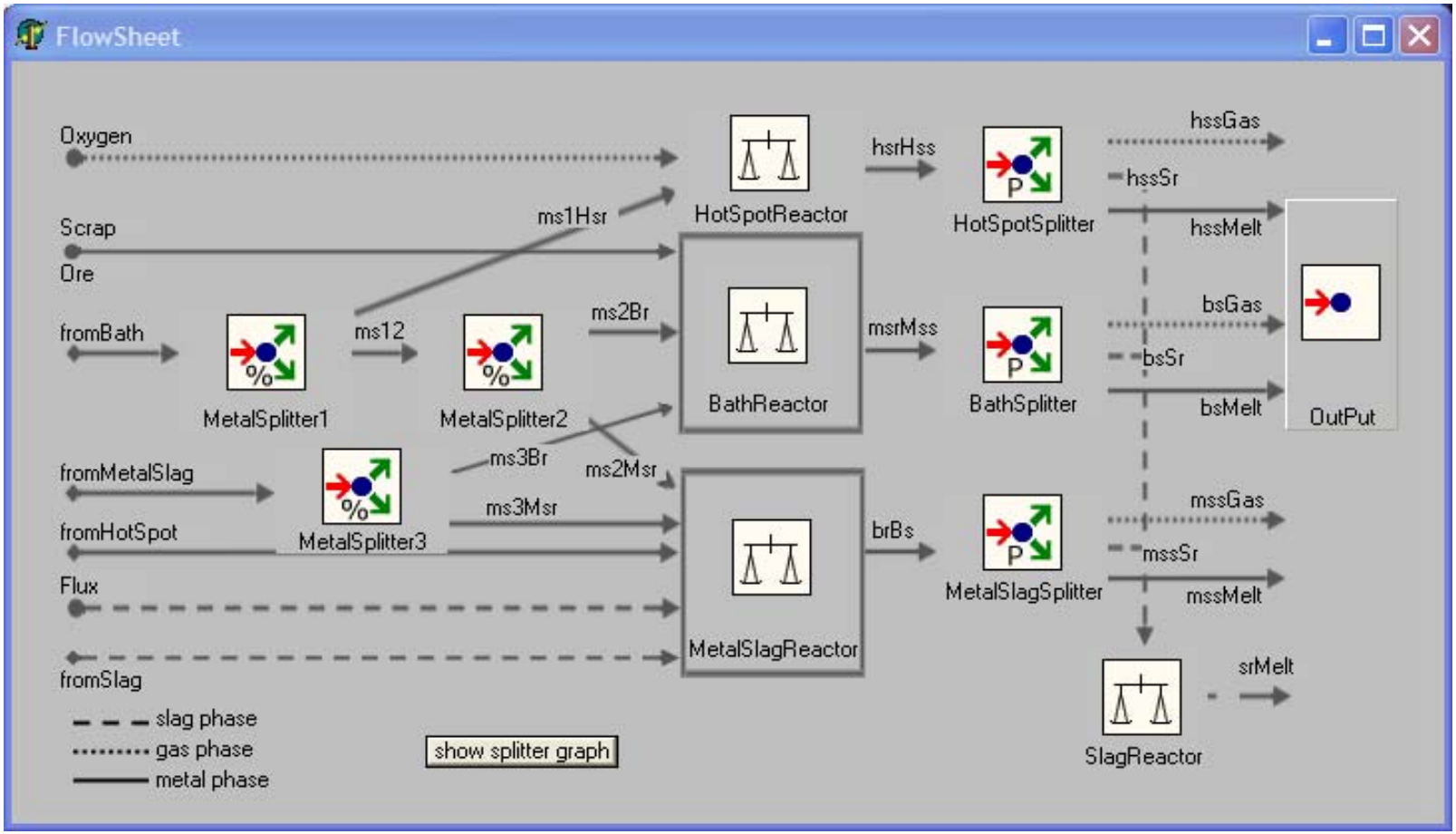
- Original Model: Traebert model
- New LD-Sage Model
  - Flowsheet
  - Preliminary results
  - The liquid slag issue
  - Reconsider the Traebert Model
  - Model redesigned
  - Aspect of simulating with SimuSage

Original Model:Traebert Model (1999)

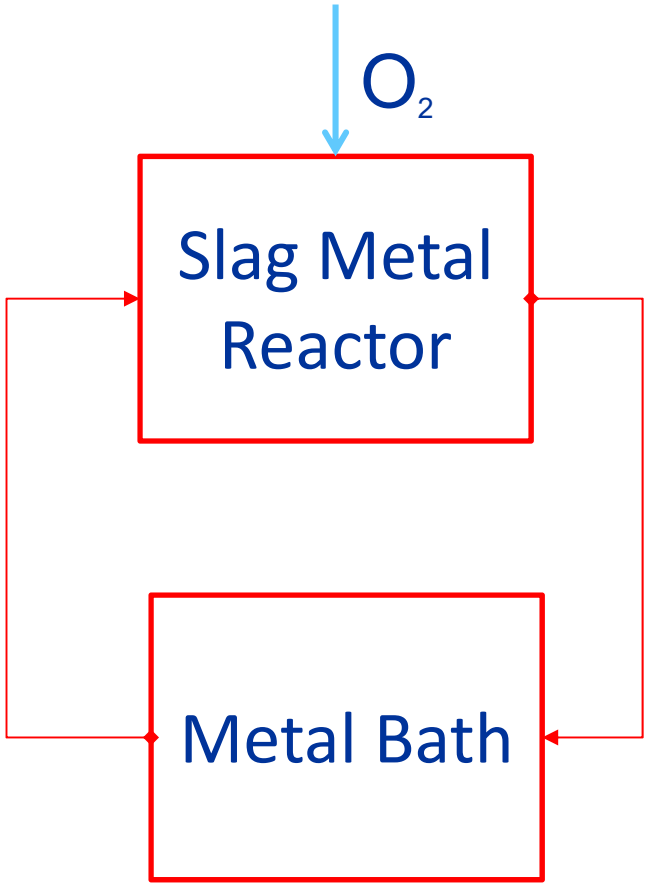




Flowsheet of the Traebert Model

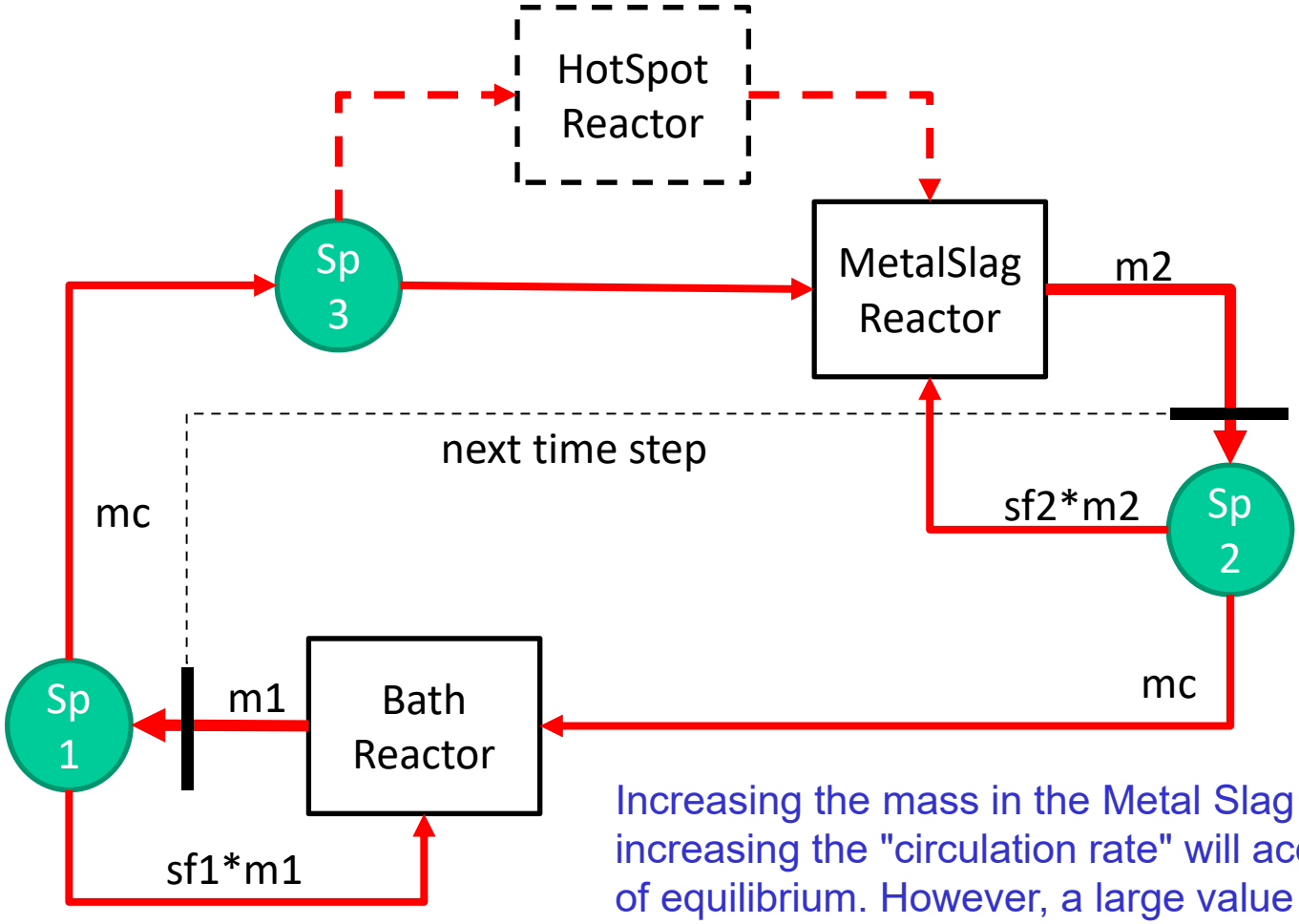


First new LD-Sage concept (2015)



New Pattern of Metal Circulation*:

*the contribution of scrap dissolution to m1 is not shown



In this :

$$sf1 = 1 - \frac{mc}{m1}$$

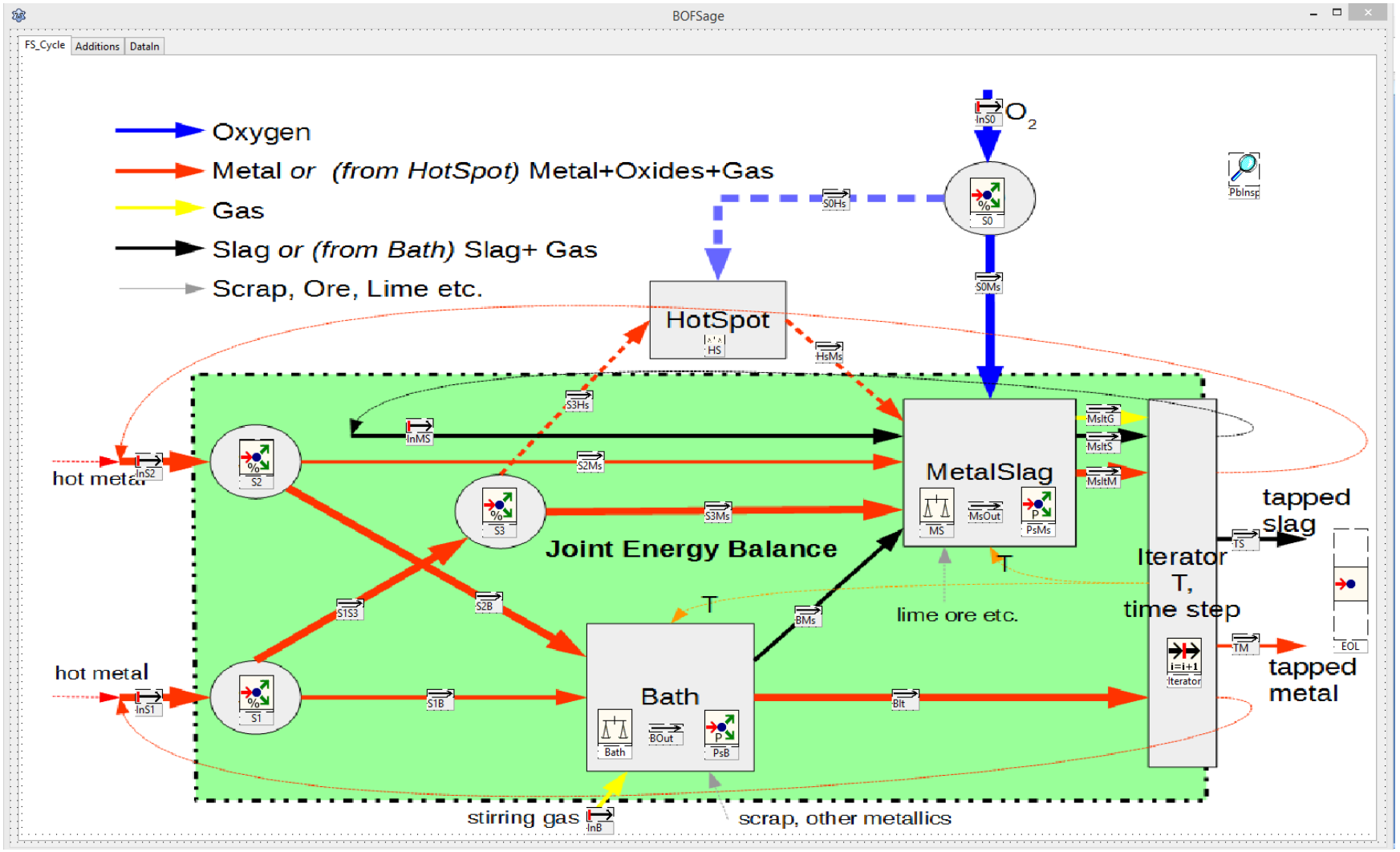
$$sf2 = 1 - \frac{mc}{m2}$$

mc = circulation rate* Δt
Δt = iteration time step

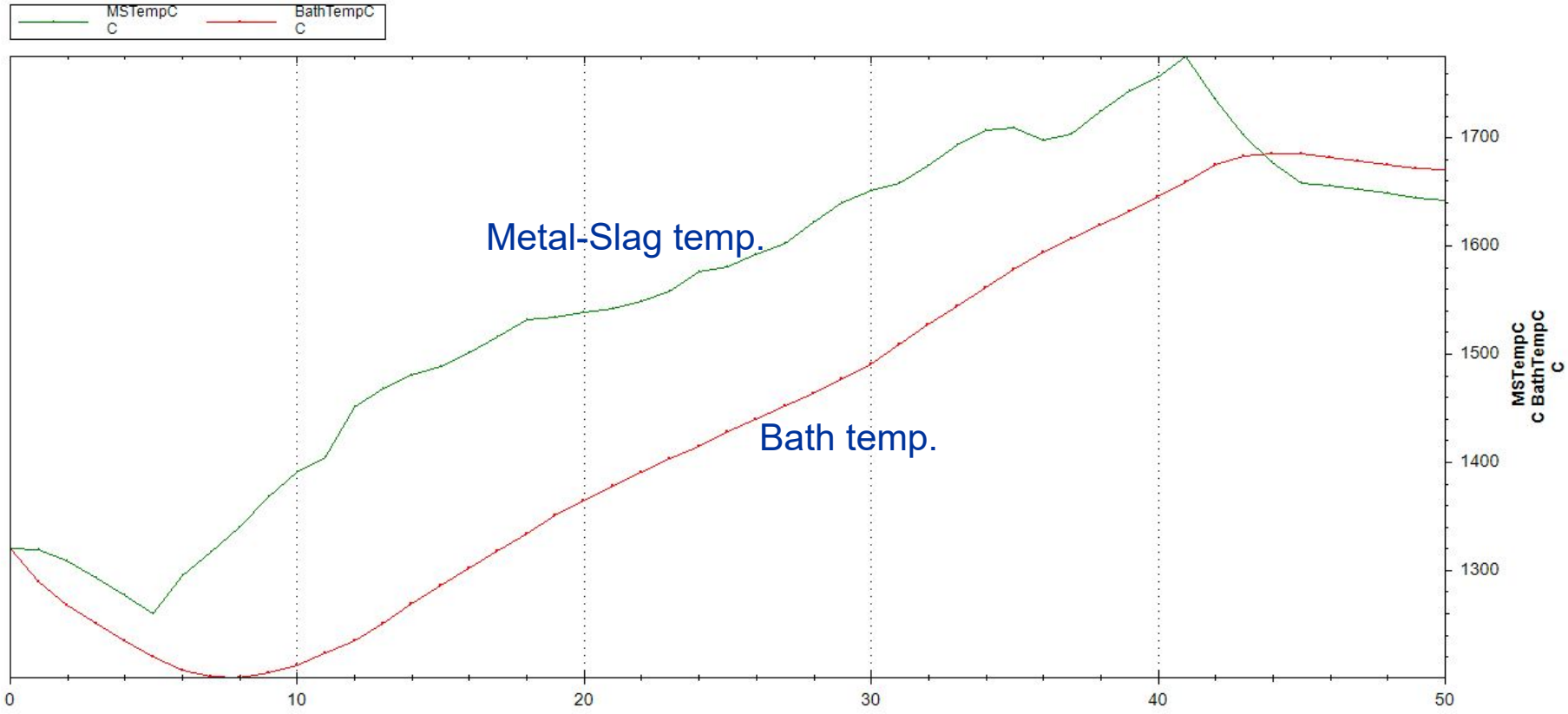
Since mc cannot exceed m1 or m2
high circulation rates will require small Δt .

Increasing the mass in the Metal Slag Reactor m2 as well as increasing the "circulation rate" will accelerate the achievement of equilibrium. However, a large value for m2 will mean that the process is close to equilibrium right from the beginning.

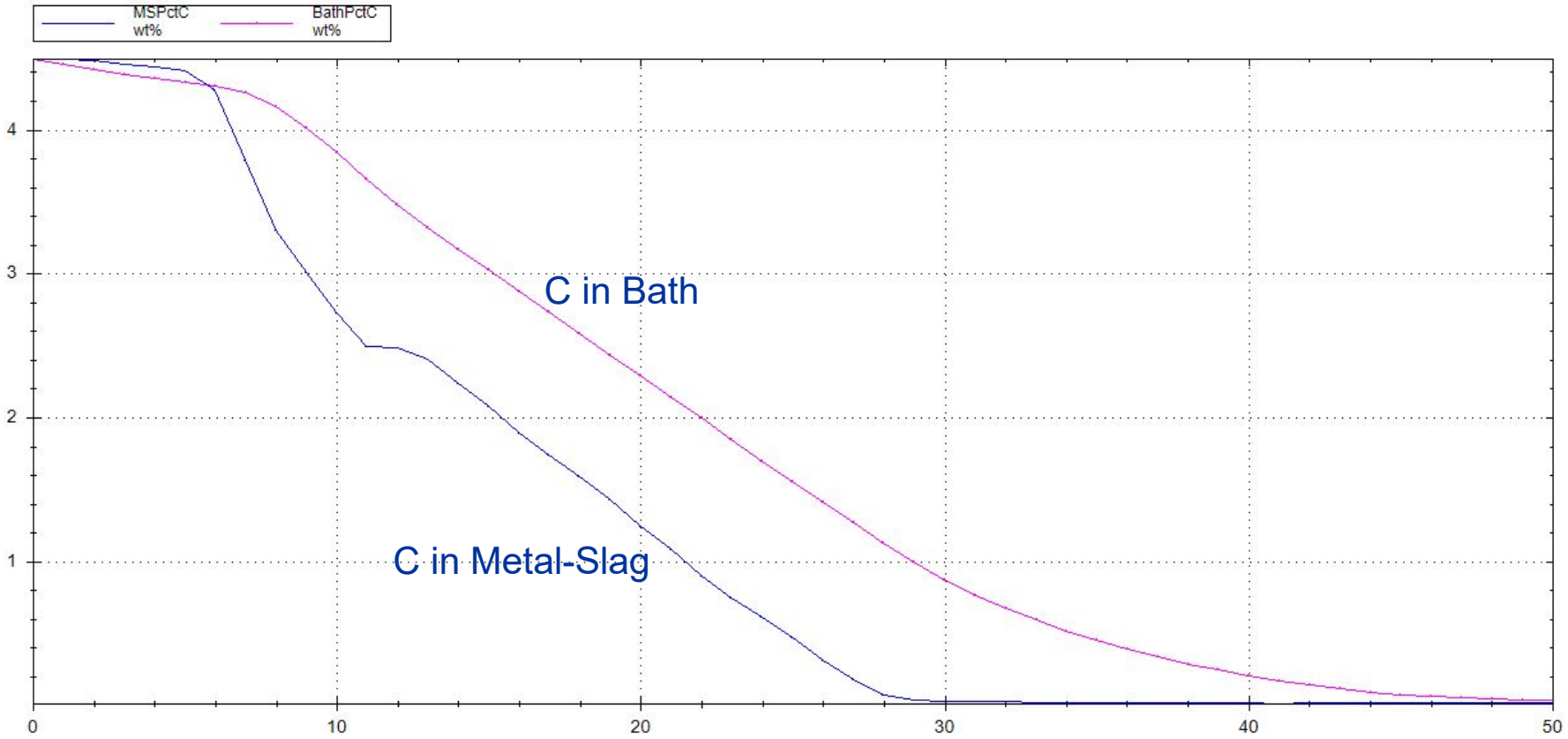
Flowsheet of the new LD-Sage model



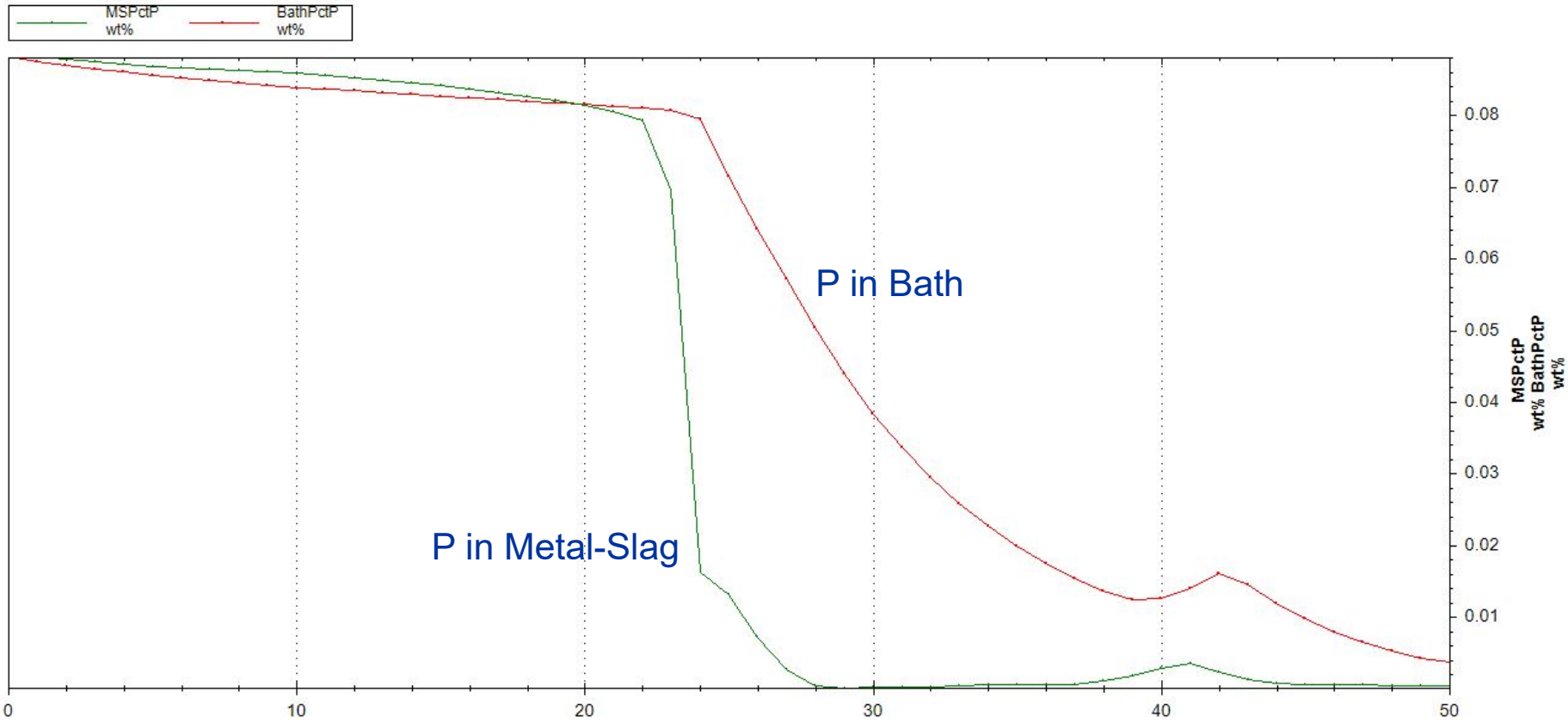
Preliminary results of the first new LD-Sage model
Temperatures in Model Cells vs time



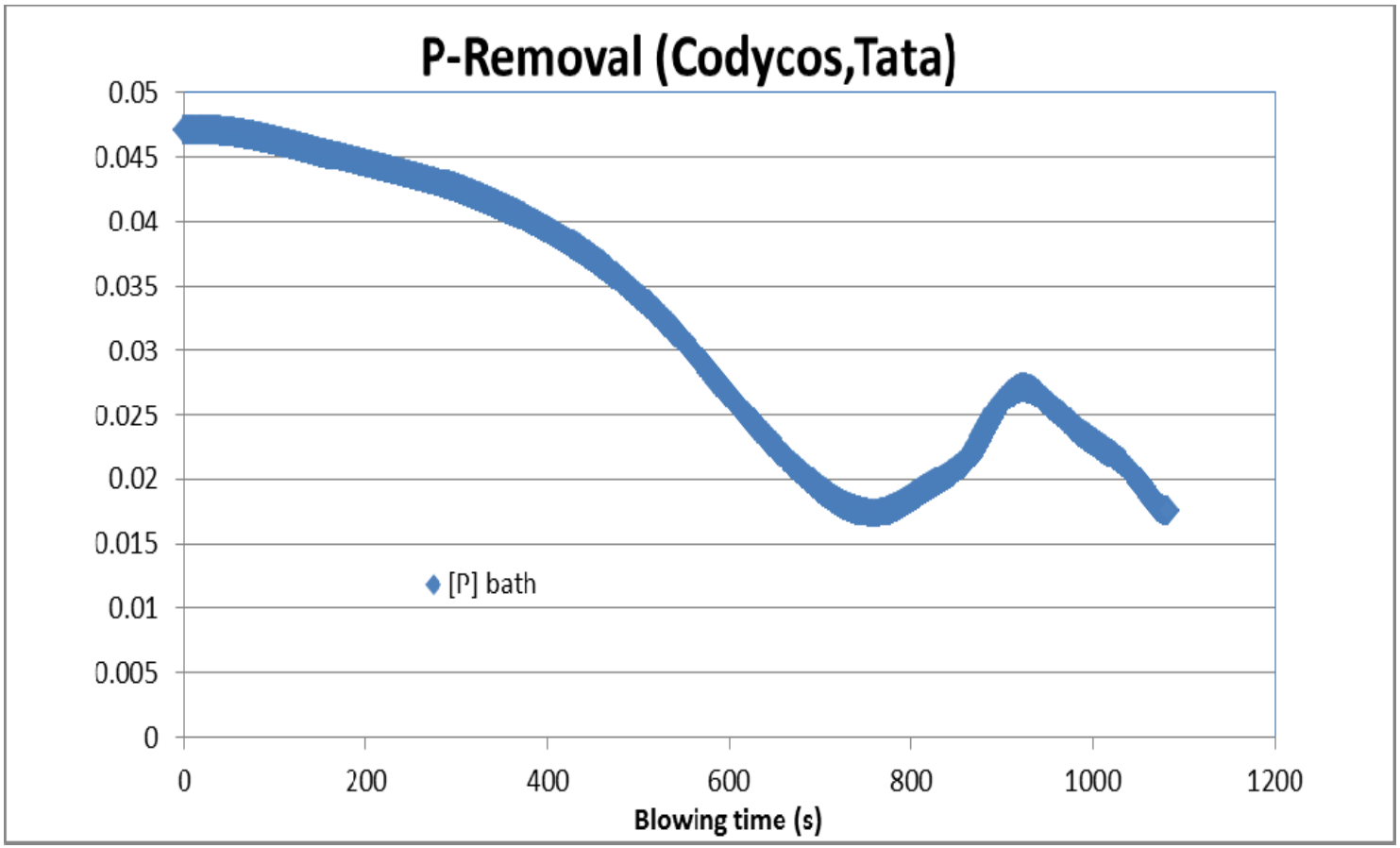
Preliminary results from new LD-Sage model
Mass% C in Model Cells vs time



Preliminary results from new LD-Sage model
Mass% P in Model Cells vs time



P-removal profile calculated by a project partner model (Tata, Codycos model)



- KTH: Laboratory experiments on lime dissolution – what sort of slag are we to use?
  - 1st revelation: lime in a sea of slag is not the correct picture because initially there is an enormous amount of lime and very little slag
  - 2nd revelation: equilibrium calculations show that there is no liquid slag in contact with metal in the first half of the blow (this was found by other authors as well)

- The second point meant that we checked our database against literature and other data bases

  => good agreement with literature (Phase diagrams)
  => consistency of results with respect to equilibria between liquid metal, lime and oxygen: no slag formation

Final conclusion: → Model needs to be redesigned

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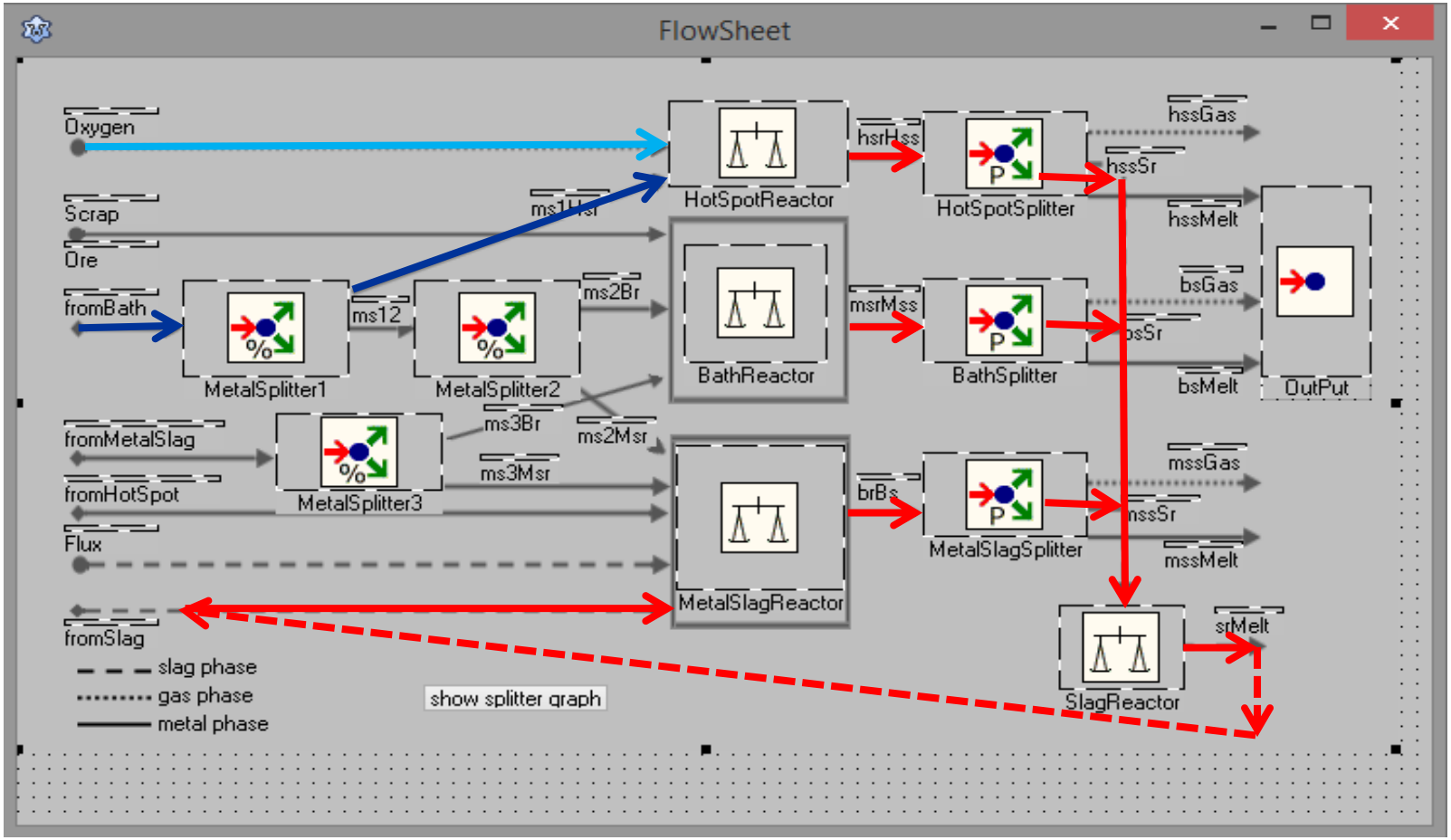
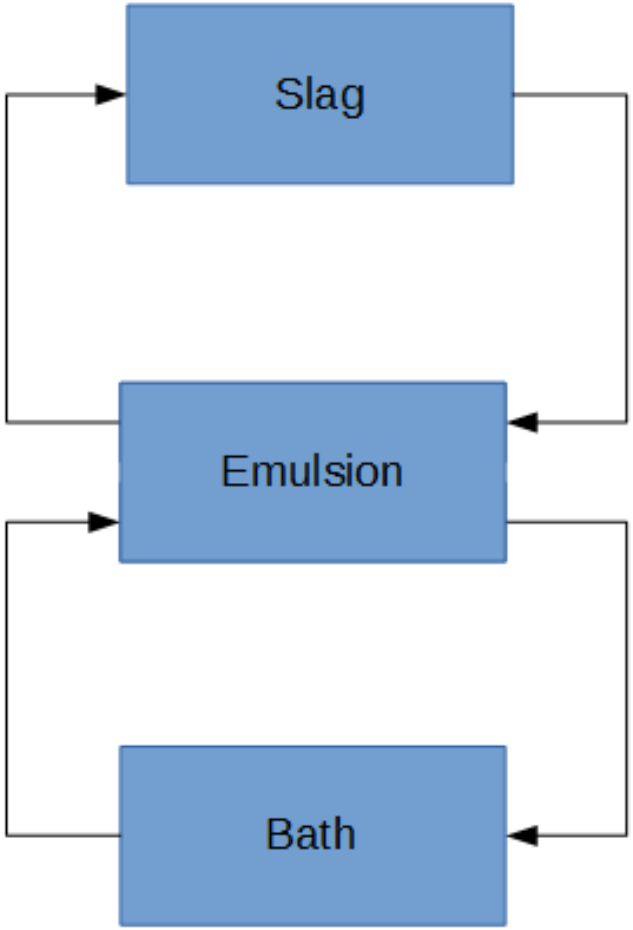
Why did the Traebert Model show liquid slag?



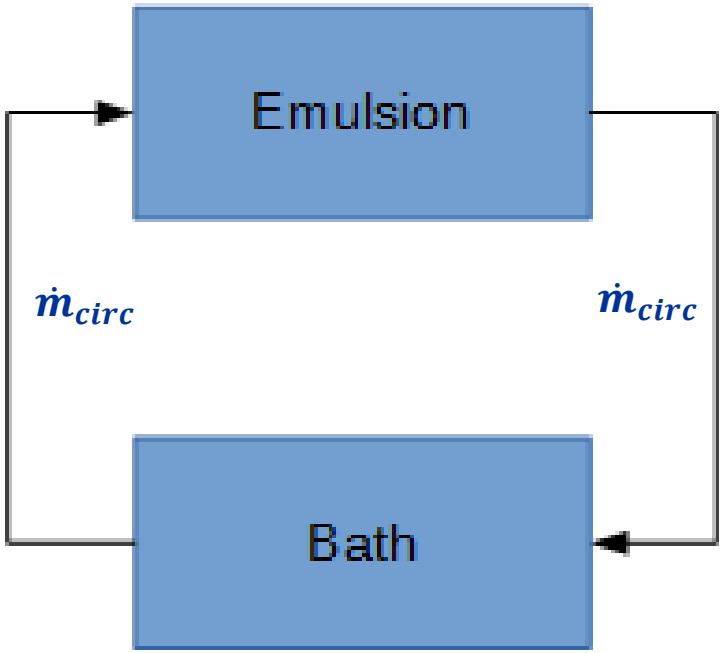
LD-Sage model including a buffer of oxides and slags



Simulating dynamic processes with SimuSage:

residence time/circulation rate/ reactor size

$t_{r,E}$; m_E



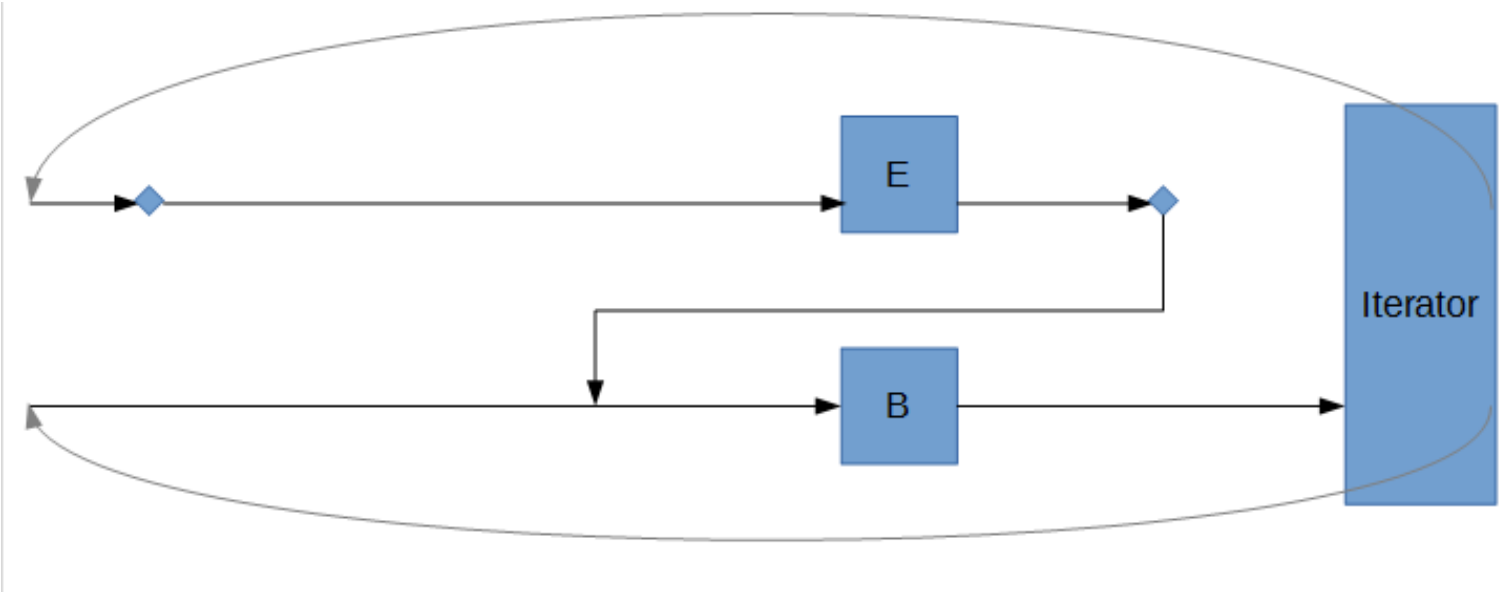
$t_{r,B}$; m_B

Reactor size

$$m_E = \dot{m}_{circ} * t_{r,E}$$

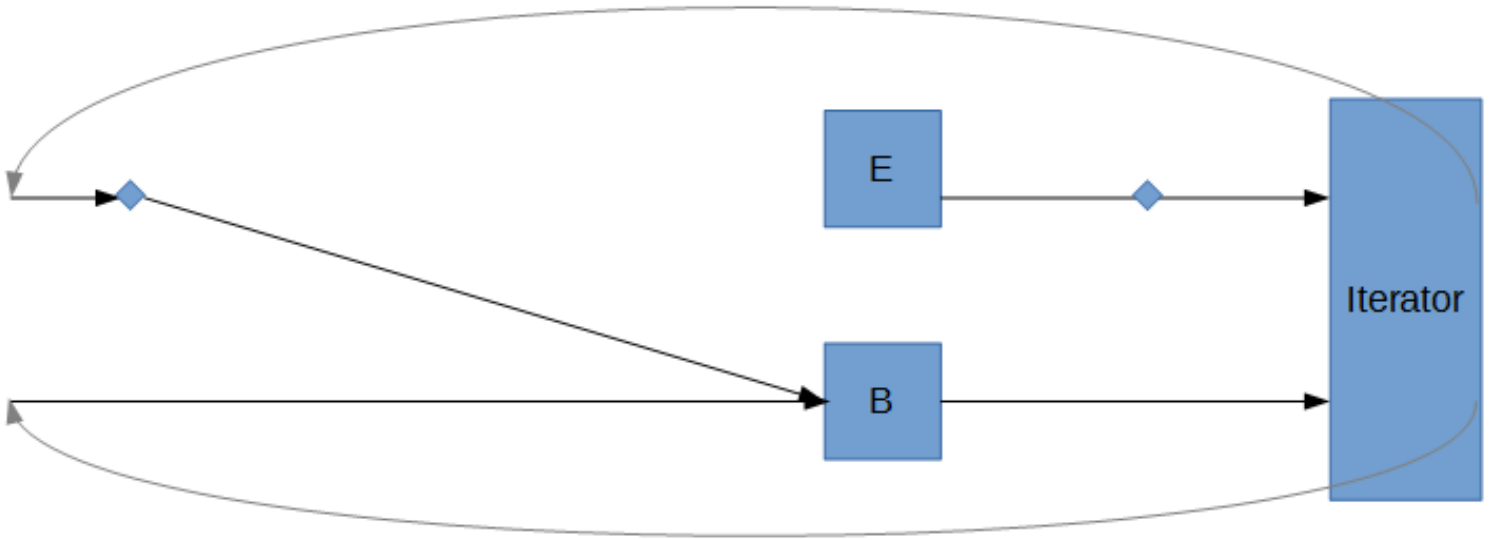
$$m_B = \dot{m}_{circ} * t_{r,B}$$

Simulating dynamic processes with SimuSage:
residence time and circulation rate



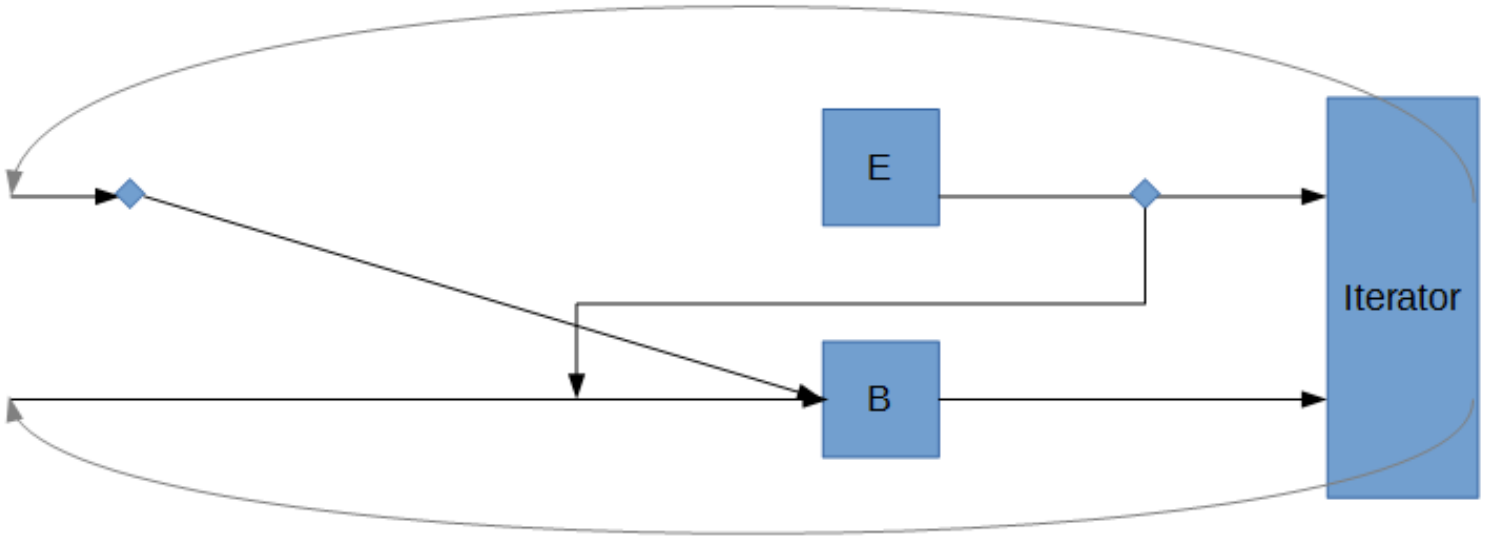
$$t_{r,E} = 0$$

Simulating dynamic processes with SimuSage: residence time and circulation rate



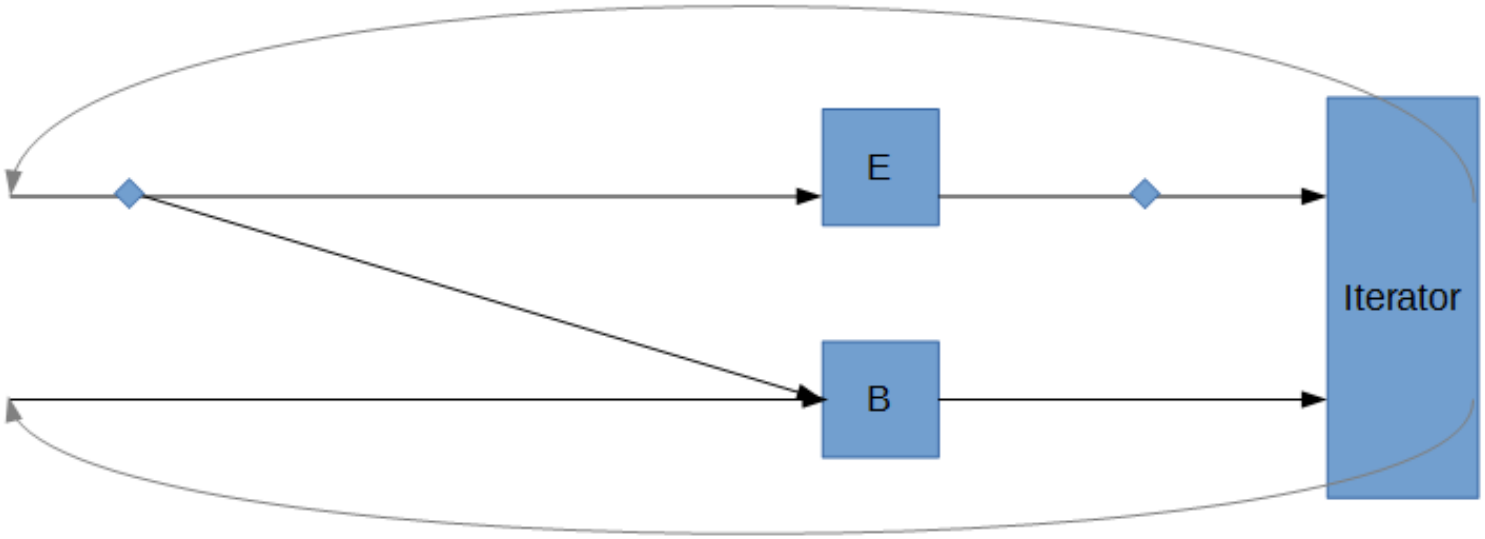
$$t_{r,E} = t_{timestep}$$

Simulating dynamic processes with SimuSage:
residence time and circulation rate



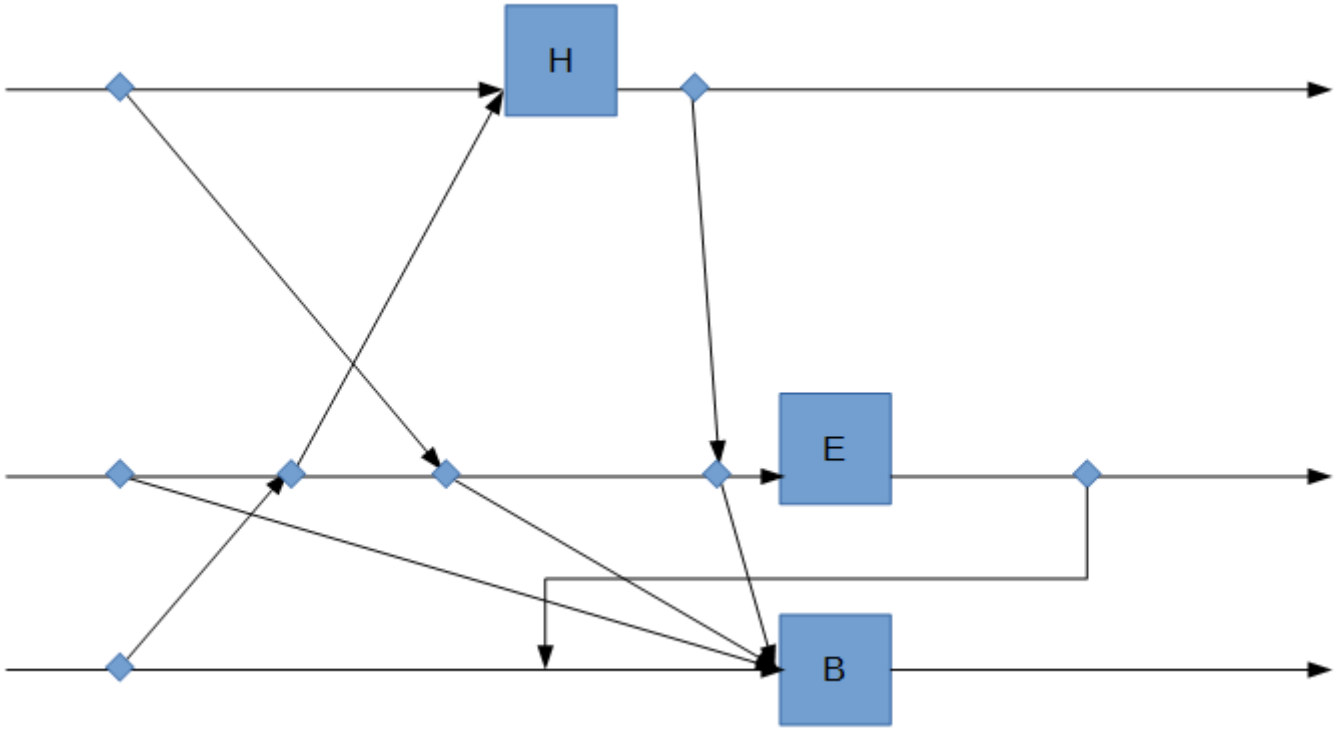
$$t_{r,E} < t_{timestep}$$

Simulating dynamic processes with SimuSage: residence time and circulation rate

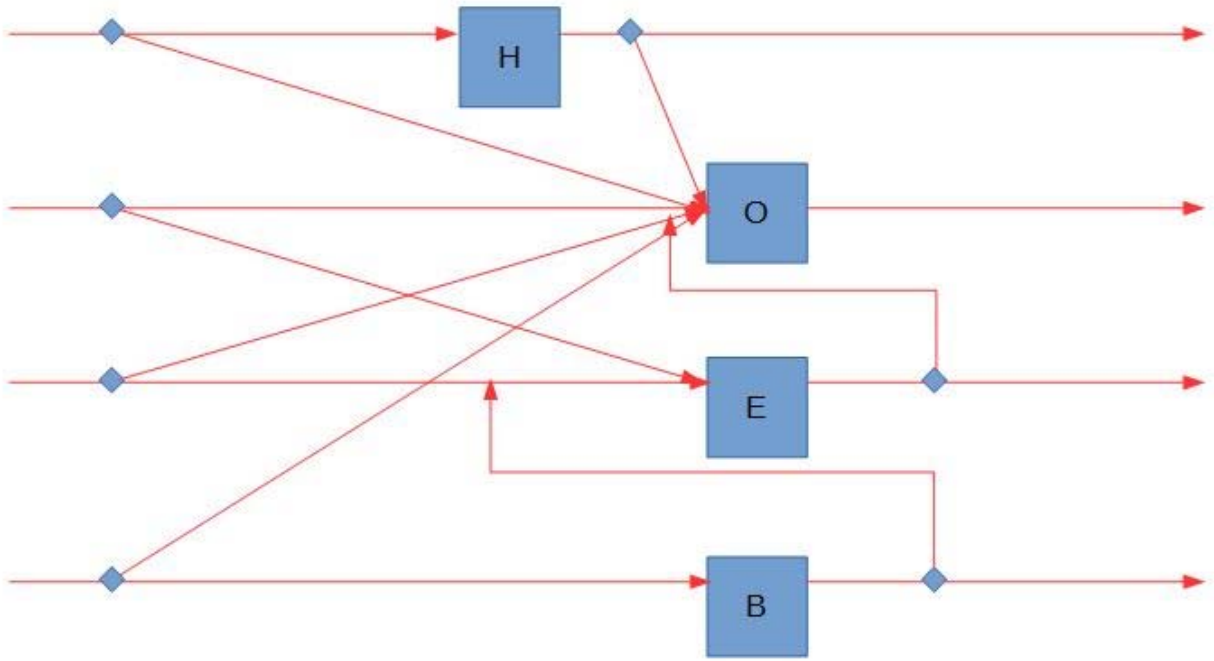


$$t_{r,E} > t_{timestep}$$

Sketch of the new LD-Sage model Flowsheet - liqMetal



Sketch of the new LD-Sage model
Flowsheet - slag



We are looking forward to presenting the results of the new model next year !

Thank you for your attention !