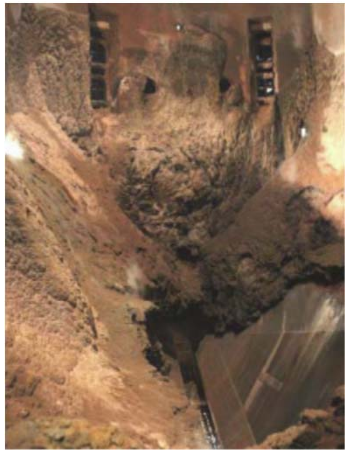
Recent advances in modelling of coal ash behaviour in the VerSi Project

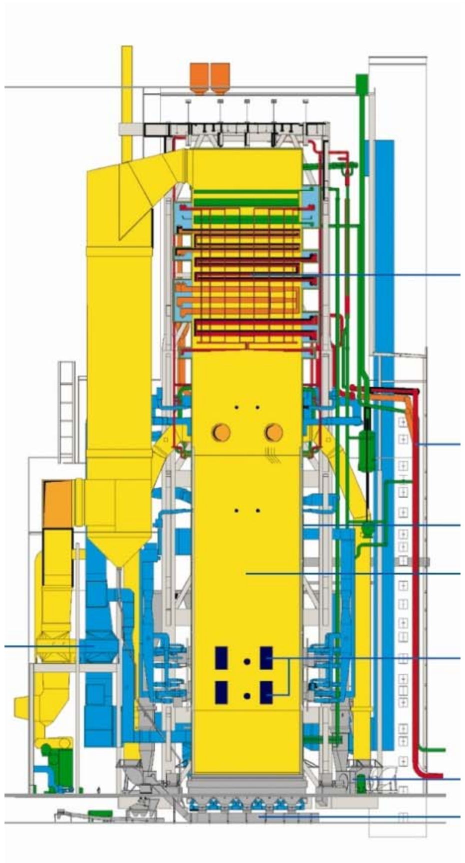
GTT User Meeting, 29th June to 1st July 2016

K. Hack[1], T.Jantzen[1], M. Dohrn[2], M. Müller[2]

[1]GTT-Technologies [2]FZJ IEK-2

Motivation





Forms of slagging and fouling

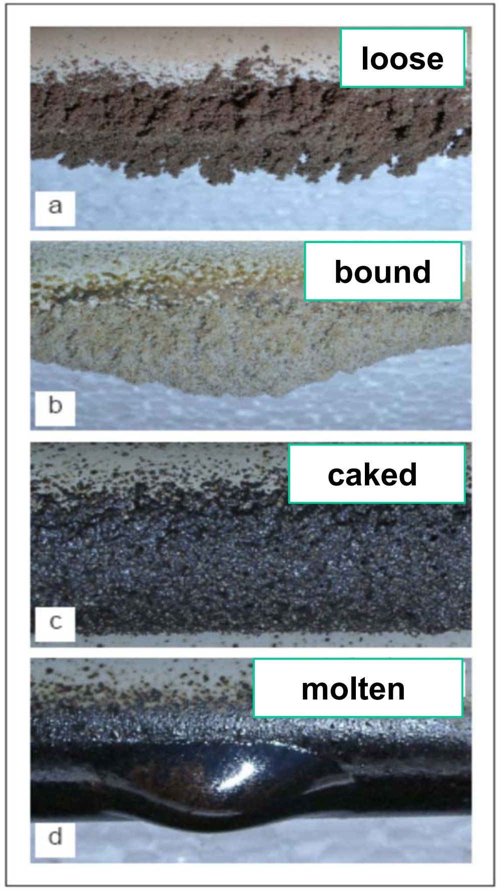
Fouling

Sintering

Slagging

f(T)

f(ash elements)



Slagging and Sintering must be technically manageable or preventable !

The Project VerSi

- Project Leader: University of Stuttgart, IFK
  Institut für Feuerungs- und Kraftwerkstechnik
- Partners: Research Center FZJ-IEK2 (Jülich)
  SMEs: RECOM Services (Stuttgart),
  GTT-Technologies (Herzogenrath)

- Industrial Supporters:
  EON, Clyde-Bergemann, Vattenfall, ALSTOM

Goals

- Collection of plant data concerning ash/slag formation and deposits
- Generation of a suitable thermodynamic database
- Generation of a model based on interlinked local equilibria
- Generation of a model based on CFD
- Comparison of plant data with models
- Adjustment of models and practical applications

Work Plan VerSi project

- Data and Model for Hard Coal fired Power Plant
- Data and Model for Lignite fired Power Plant
- Model adaptation for use in plant environment

Ash compositions for Hard Coals

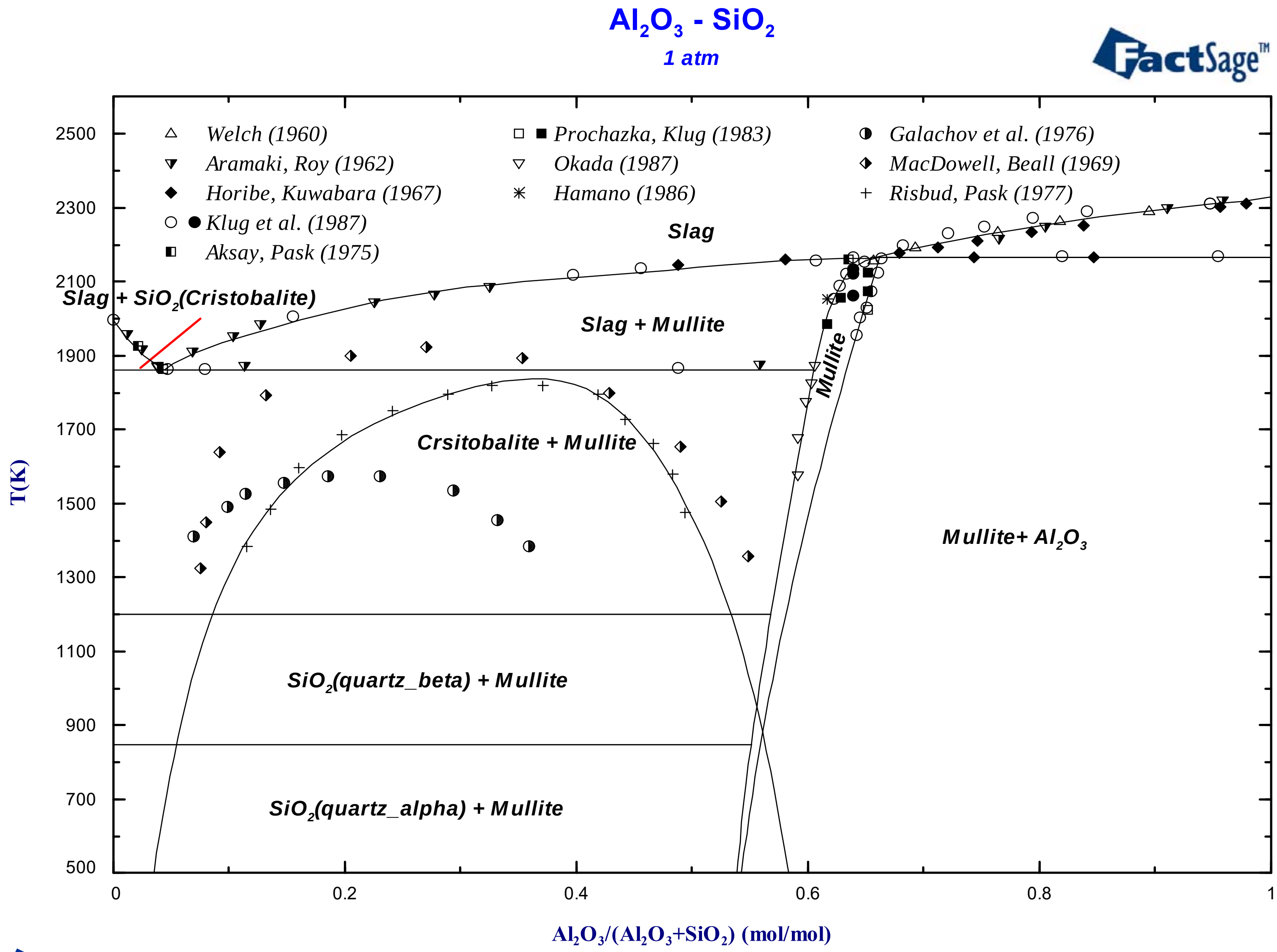
		Columbia	South Afr.	Russia	USA
Component	**Unit**	**SKC**	**SKK**	**SKR**	**SKU**
Al2O3	%	14.6	25.9	22.1	20.6
CaO	%	2.1	7.1	4.9	3.7
Fe2O3	%	15.5	15.4	6.8	14.6
K2O	%	1.4	0.7	2.9	2.4
MgO	%	1.1	0.1	0.2	0.9
Na2O	%	1.8	0.2	1.3	0.7
P2O5	%	0.1	1.5	0.5	0.2
SiO2	%	60.7	45.4	57.1	52.6
SO3	%	1.9	2.5	3.2	3.0
TiO2	%	0.8	1.4	0.9	1.1

Conclusion: The Al_2O_3-SiO_2-X subsystems are of major importance !
The most important third component is $Fe_2O_3 \rightarrow FeO_x$

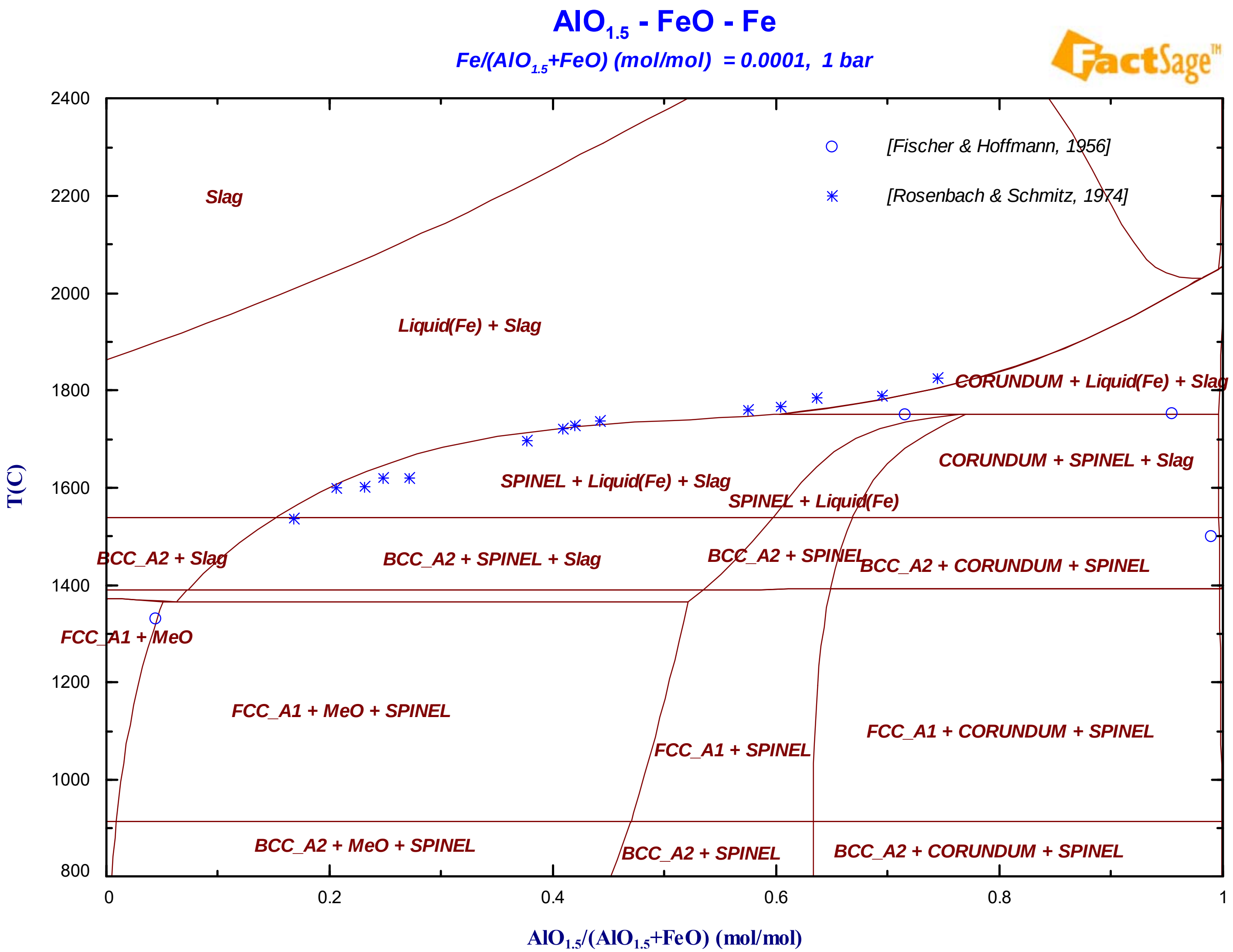
Note: Inclusion of TiO_2 is in progress.

Phase diagrams pertaining to hard coal ashes

GTT-Technologies



Phase diagrams pertaining to hard coal ashes



Phase diagrams pertaining to hard coal ashes

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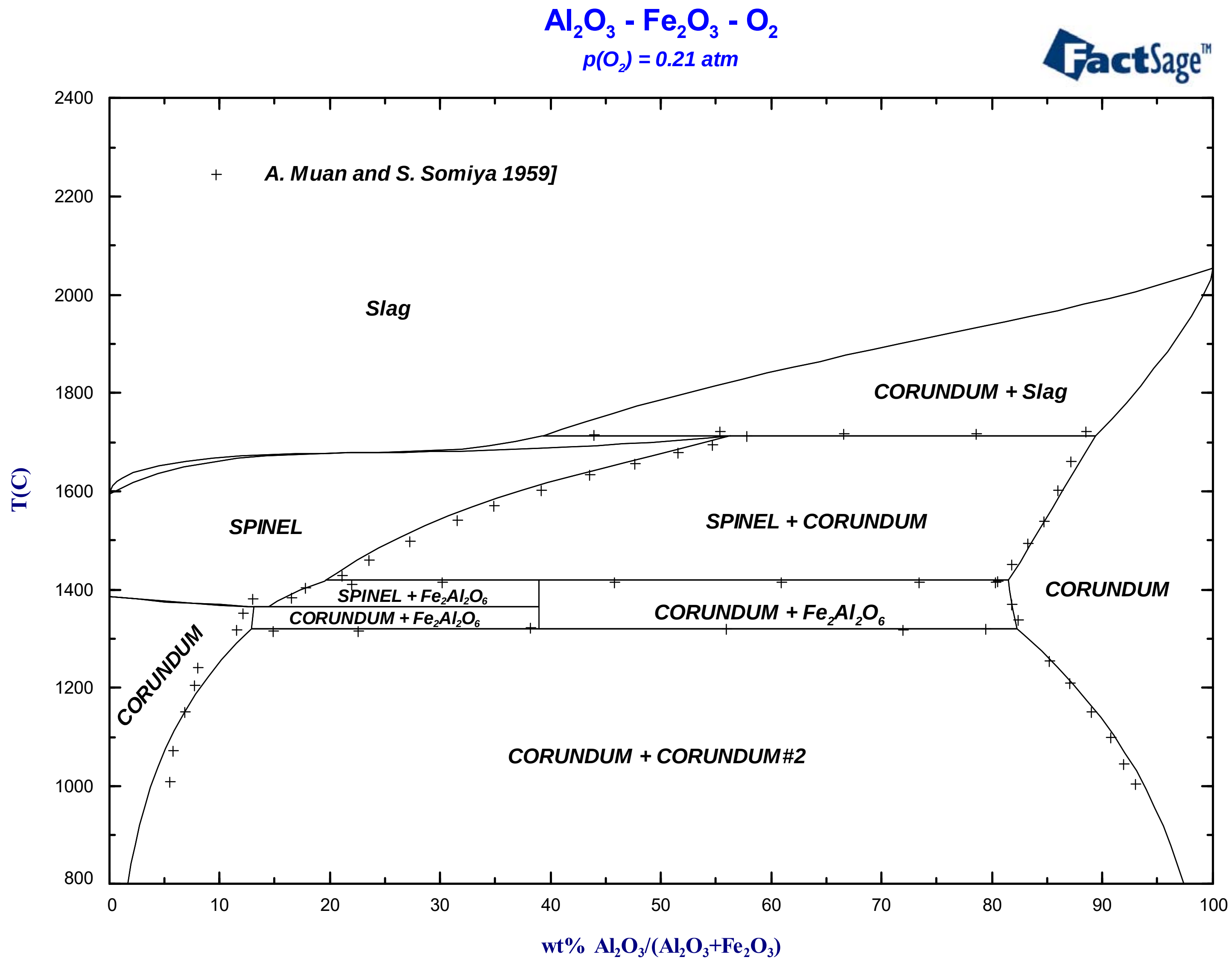
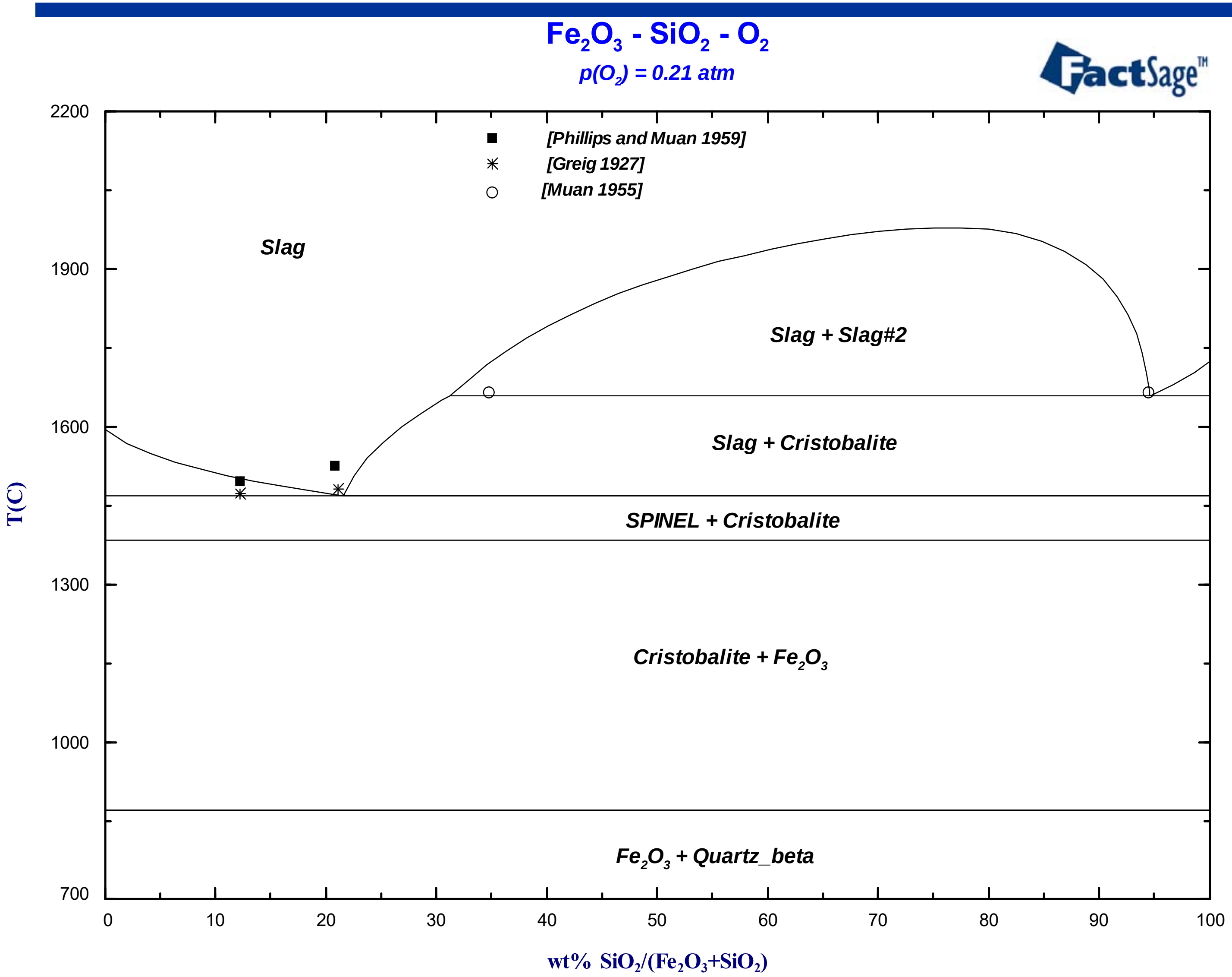


Phase diagrams pertaining to hard coal ashes



Phase diagrams pertaining to hard coal ashes

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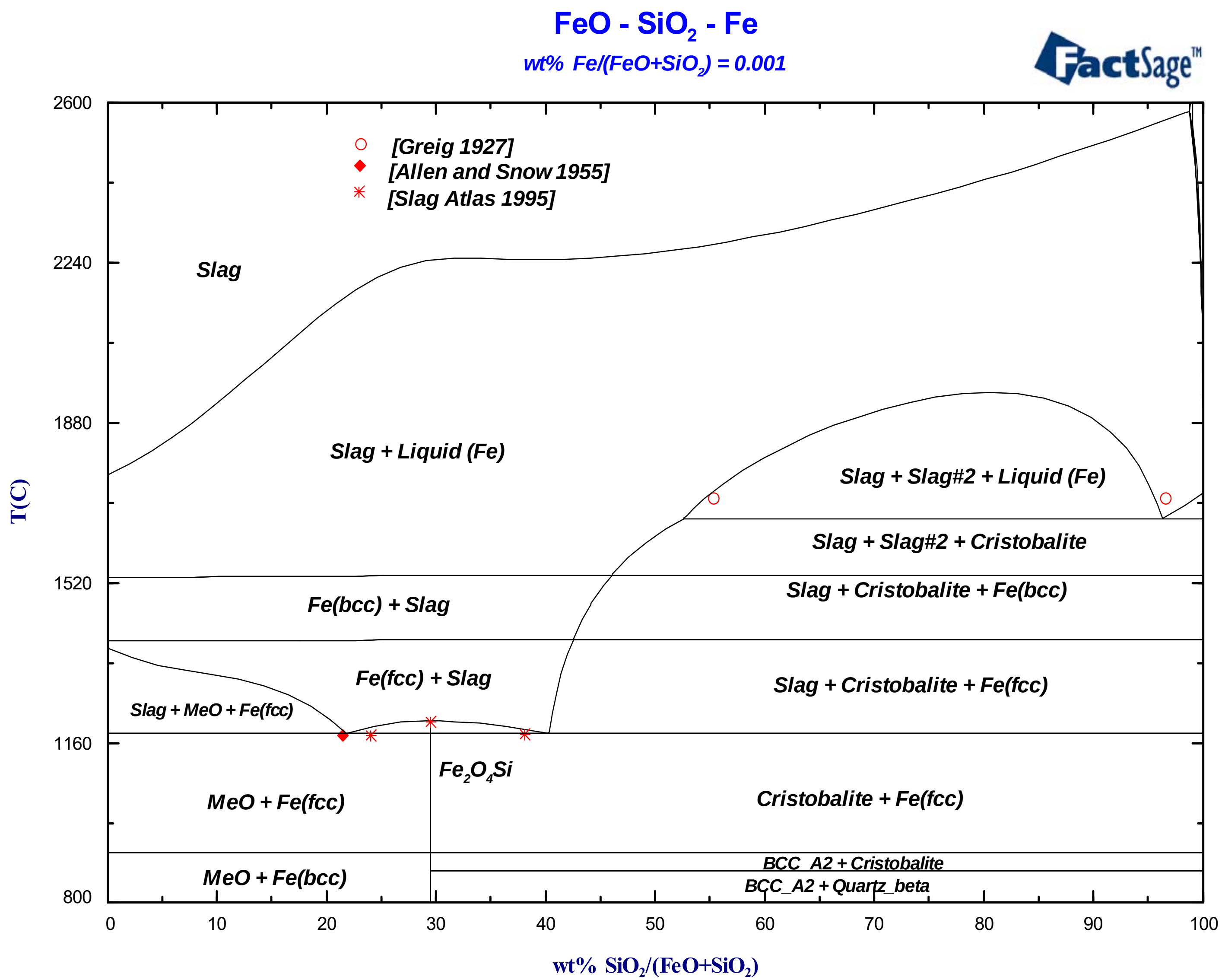

Phase diagrams pertaining to hard coal ashes

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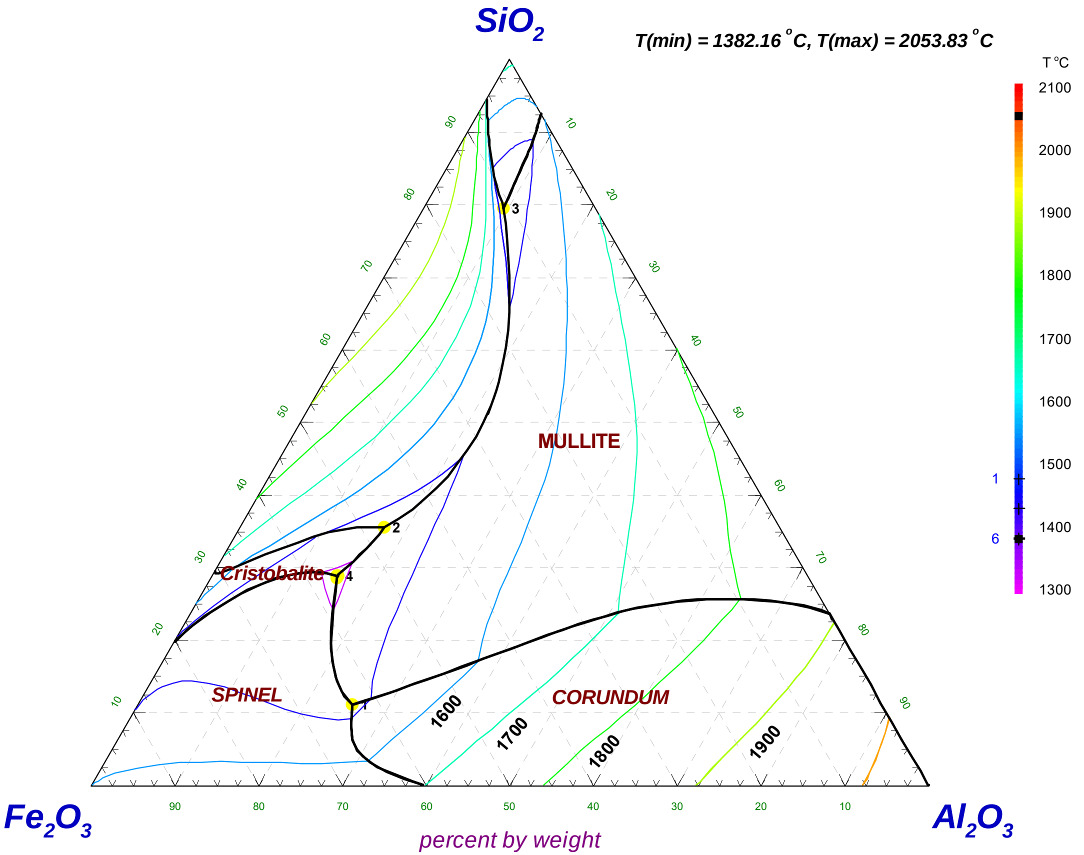
Al_2O_3 - Fe_2O_3 - SiO_2 - O_2

Projection (Slag), $p(O_2)$ = 0.21 atm, 1 atm



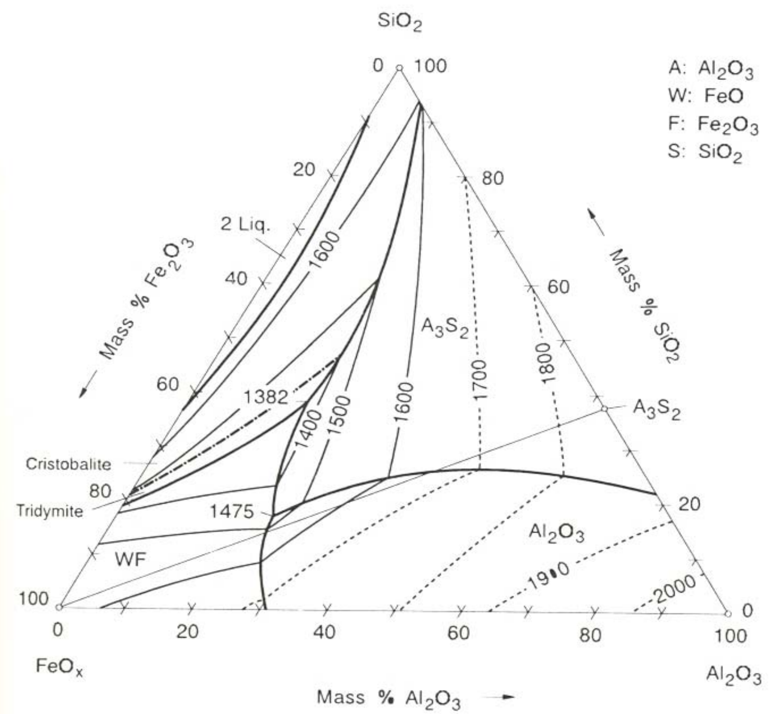


Fig. 3.184. Liquidus surface in the system Al_2O_3-FeO_x-SiO_2 in air after Muan [4], as revised by Idink, Woermann [5].

Phase diagrams pertaining to hard coal ashes

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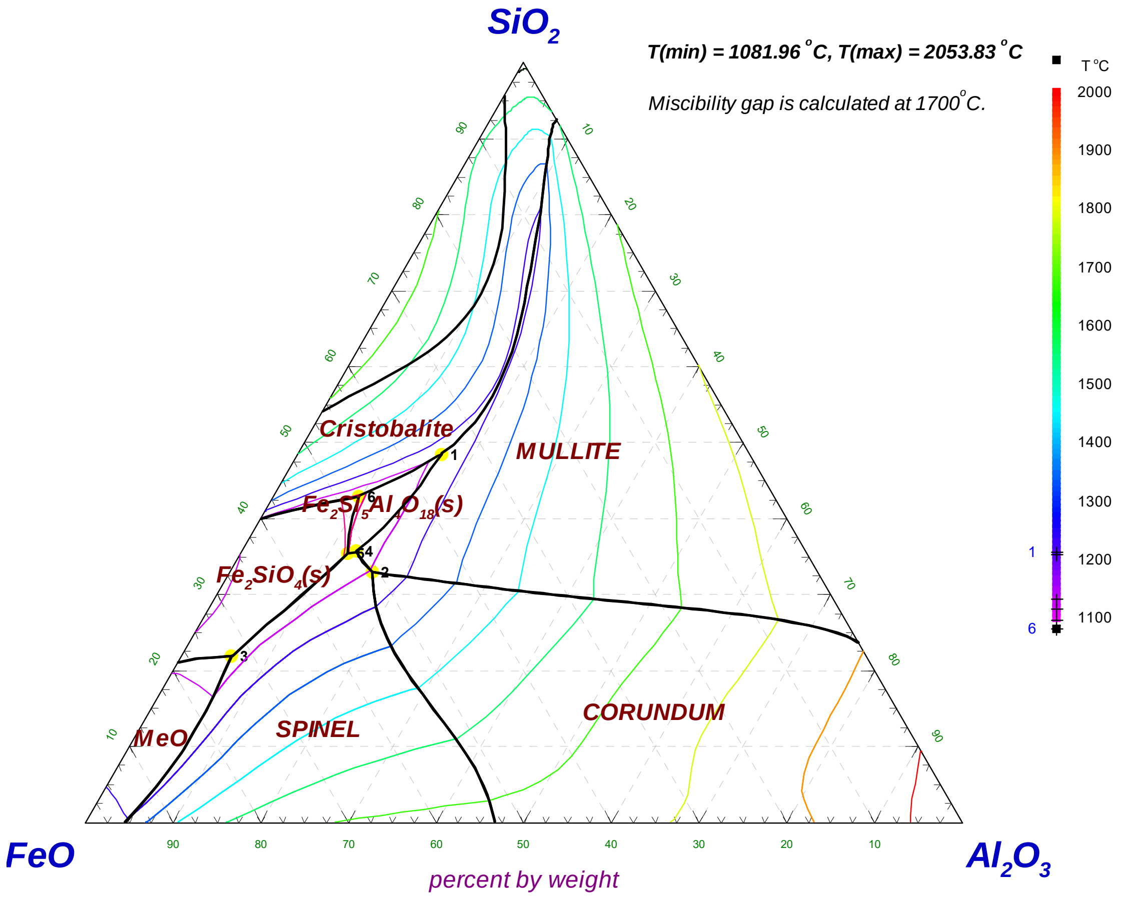
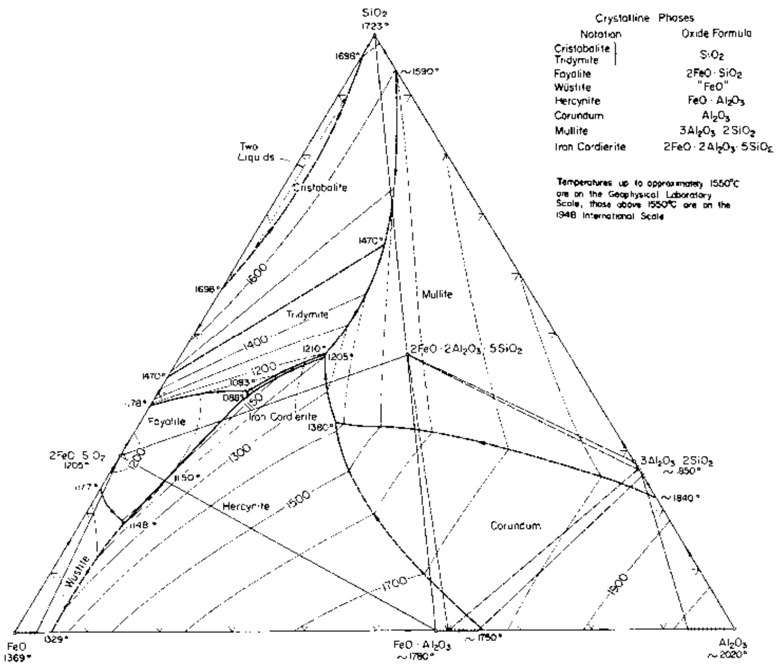
Al_2O_3 - FeO - SiO_2

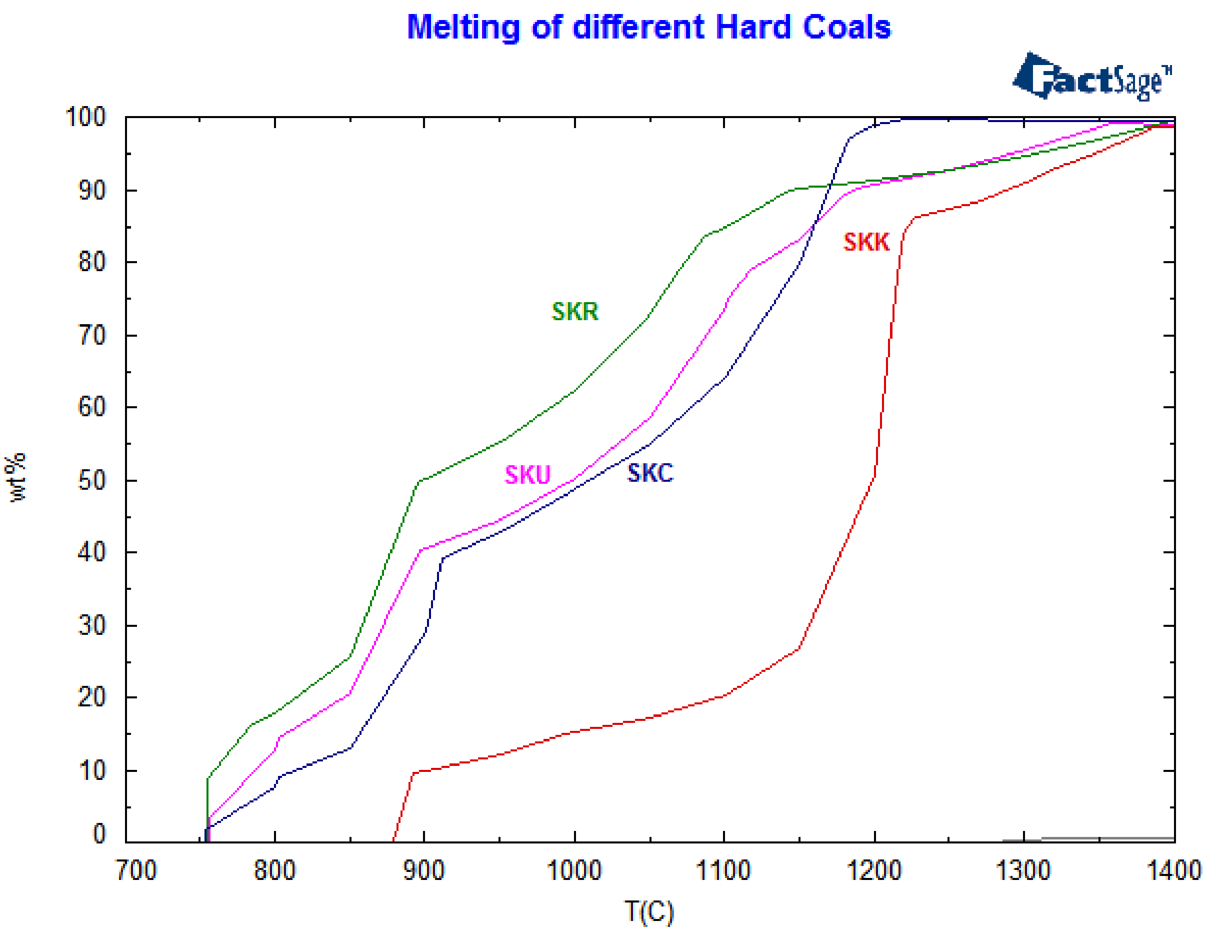
Projection (Slag), 1 atm



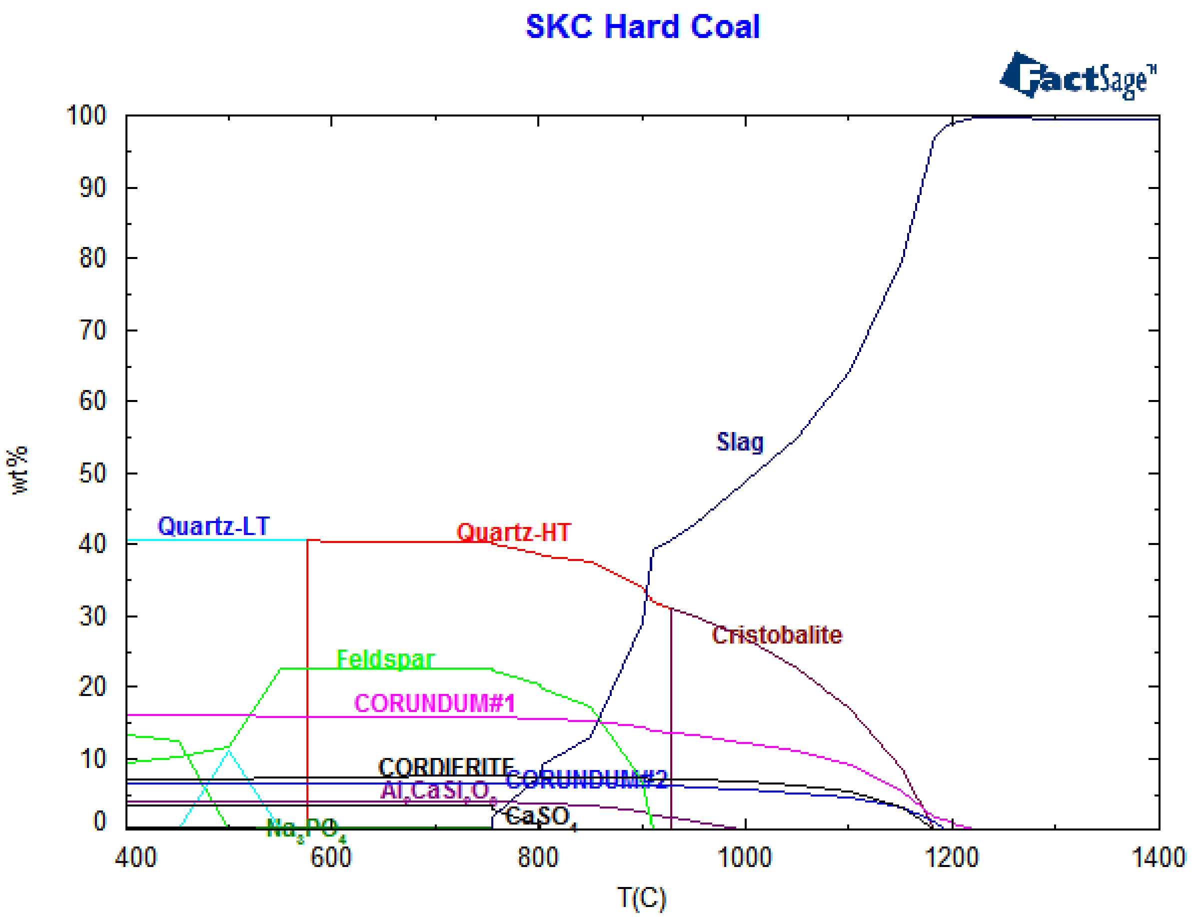


E.F. Osborn, A. Muan: „Phase Equilibrium Diagrams of Oxide Systems", Plate 9, publ. By American Ceramic Society and the Edward Orton, Jr., Ceramic Foandation, 1960.

Wt% Melt as f(T)


Melting of different Hard Coals
FactSage™
wt%
T(C)
SKR
SKU
SKC
SKK
100
90
80
70
60
50
40
30
20
10
0
700
800
900
1000
1100
1200
1300
1400

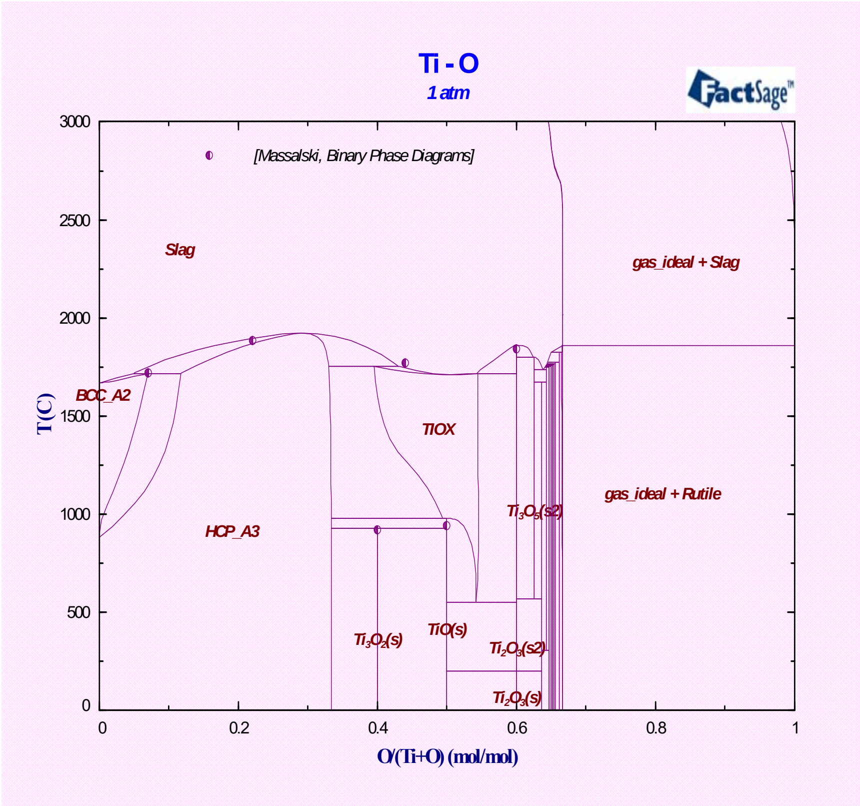
All phase amounts during melting of SKC

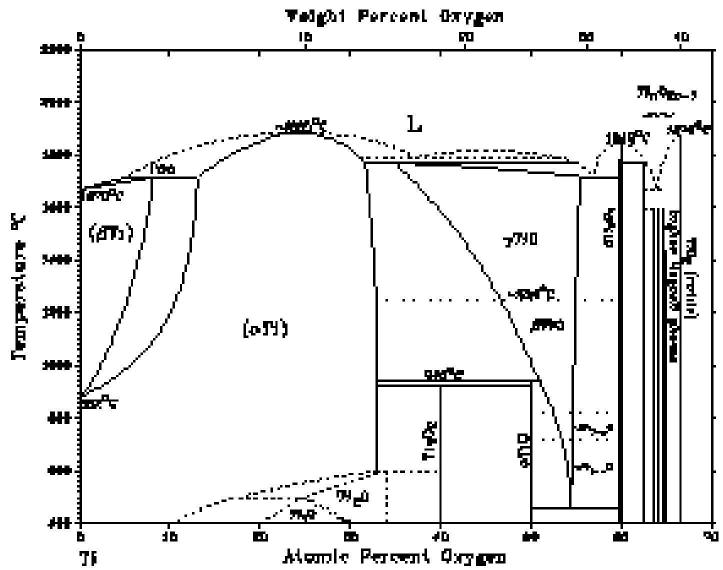


Inclusion of TiO_2

- **Binary systems**
  - *Al-O*
  - *Ti-O*
  - *Al-Ti*
  - *Al_2O_3-TiO_2*
  - *MgO-TiO_2*
- **Ternary system**
  - *Al-O-Ti*
  - *Al_2O_3-MgO-TiO_2*

Ti-O phase diagram





T.B. Massalski (ed), Binary Alloy Phase Diagrams, Second Edition, ASM International, Metals Park, OH 1990.

Isothermal section at 1100°C in Al-Ti-O

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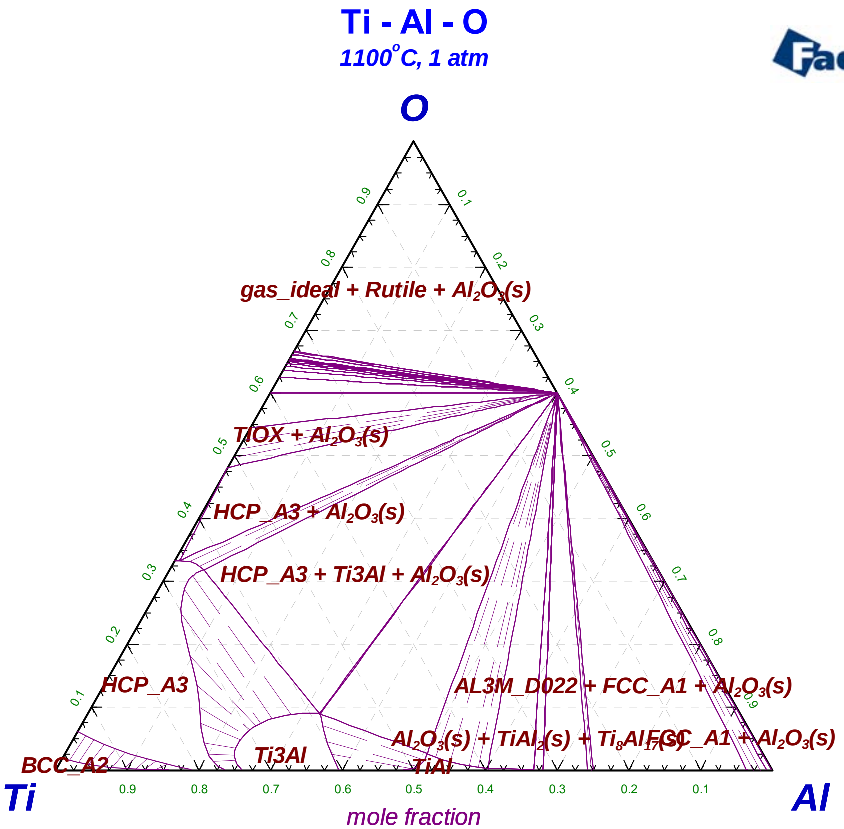


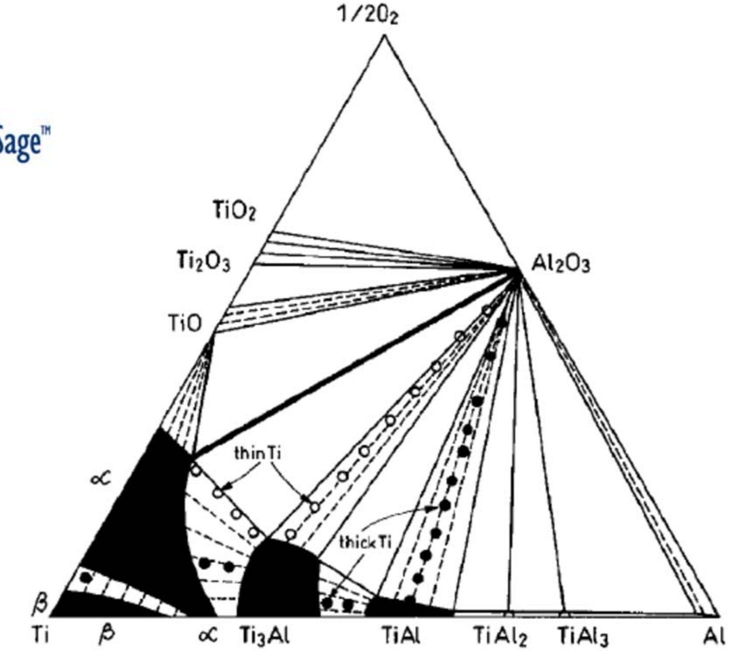
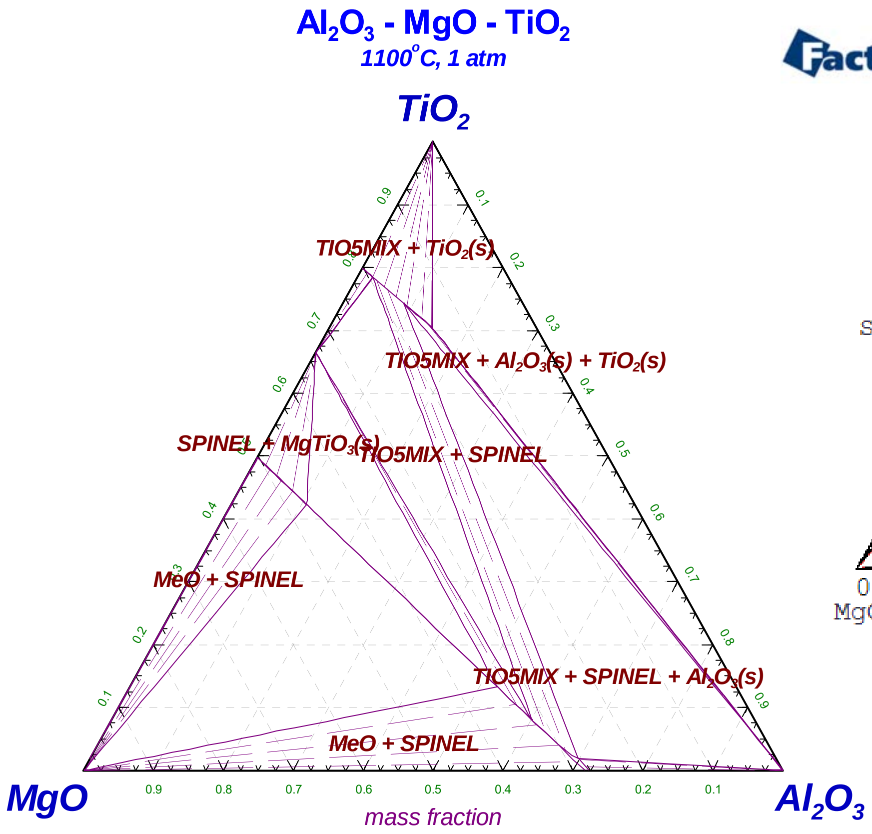
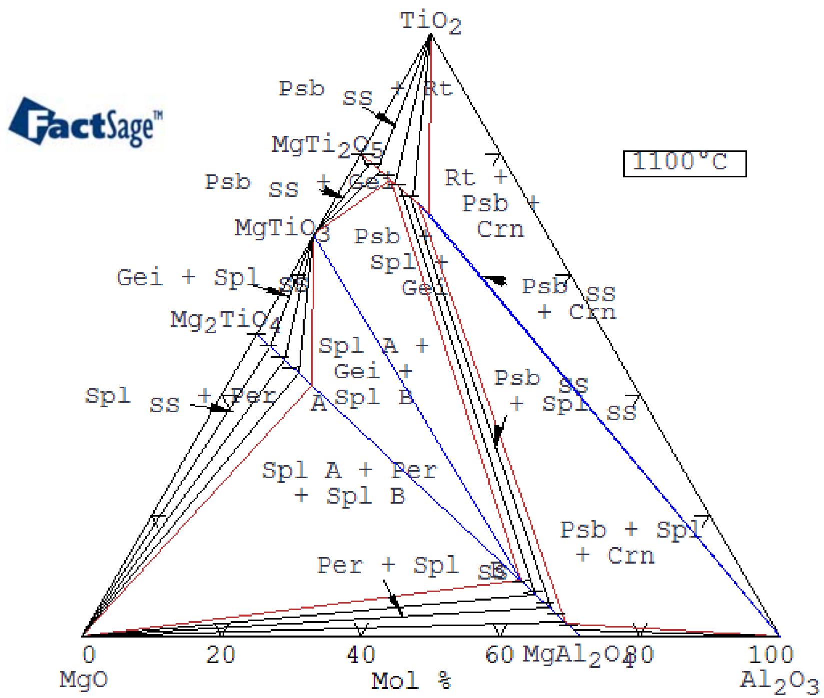


Fig. 7 Experimentally determined isothermal section of the Ti-Al-O system at 1100 °C with diffusion paths indicated [1992Li]

K. Das, P. Choudhury, S. Das. J. Phase Equilib., 23 [6], (2002), pp. 525-536.

Isothermal section at 1100°C in Al_2O_3-MgO-TiO_2





P. Boden, F.P. Glasser, Trans. J. Br. Ceram. Soc., 72[5], (1973), pp. 215-220.

Isopleth Al_2MgO_4-Mg_2TiO_4 in Al_2O_3-MgO-TiO_2

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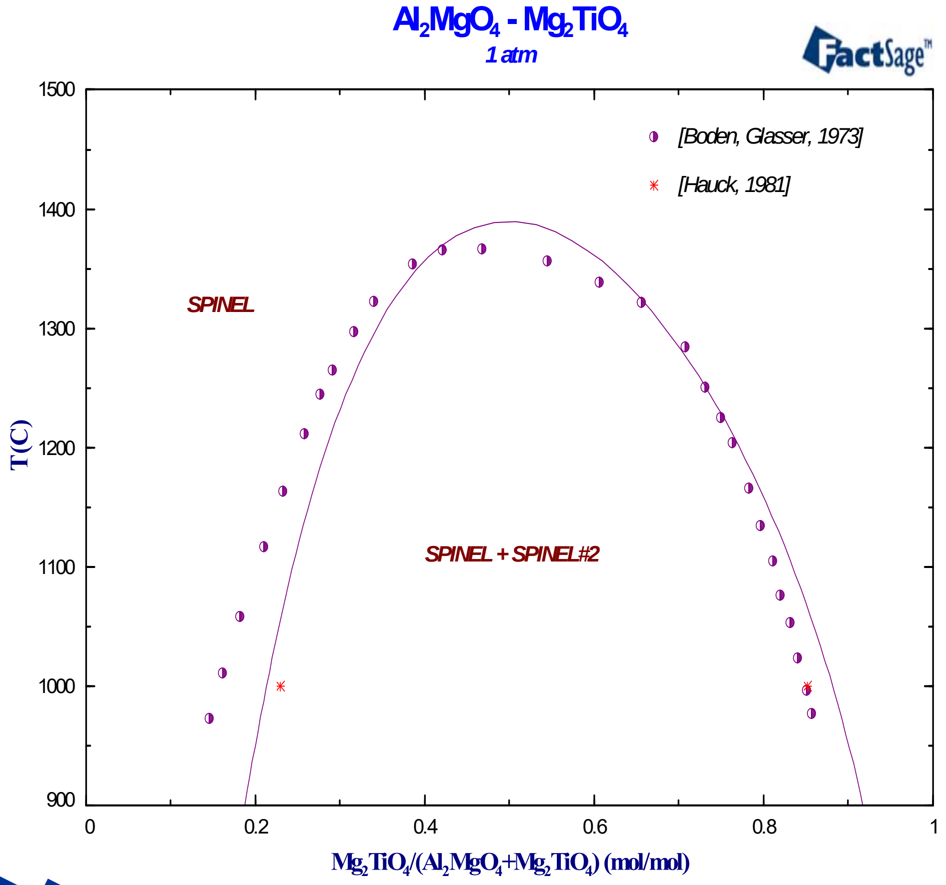
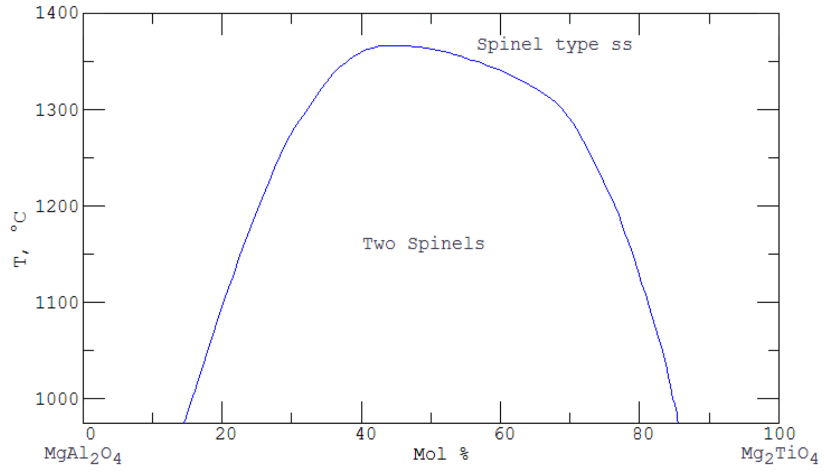
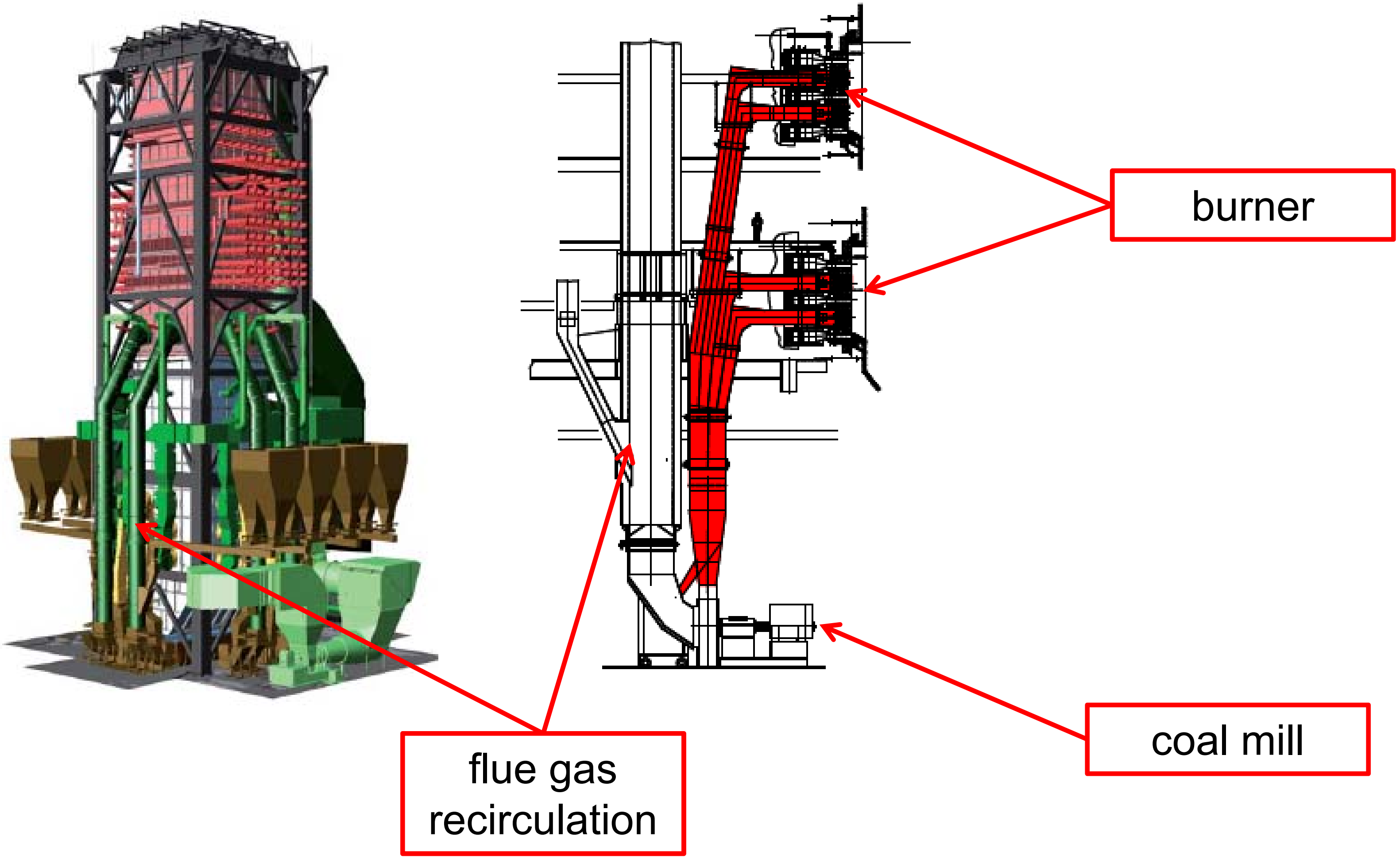
Spinel – solid solution phase with end-members
Al_2MgO_4 and Mg_2TiO_4
$(Al^{+3},Mg^{+2},Ti^{+4})_1(Al^{+3},Mg^{+2},Va)_2(Mg^{+2},\underline{Va})_2(O^{-2})_4$





P. Boden, F.P. Glasser, Trans. J. Br. Ceram. Soc., 72[5], (1973), pp. 215-220.

Model relevant Details of Boiler for Dust Combustion



Furnace chamber: SimuSage model

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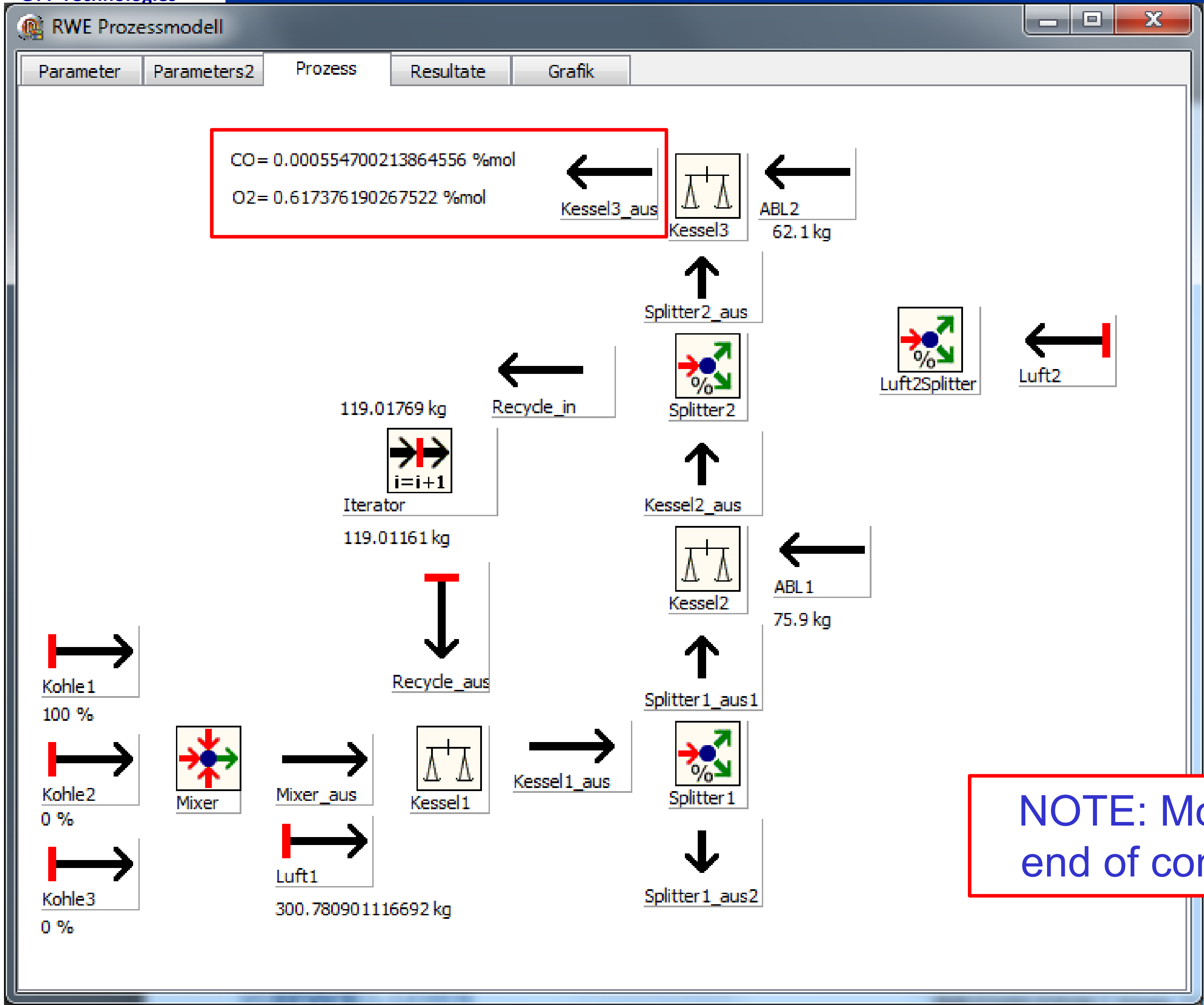


Kohle = Coal

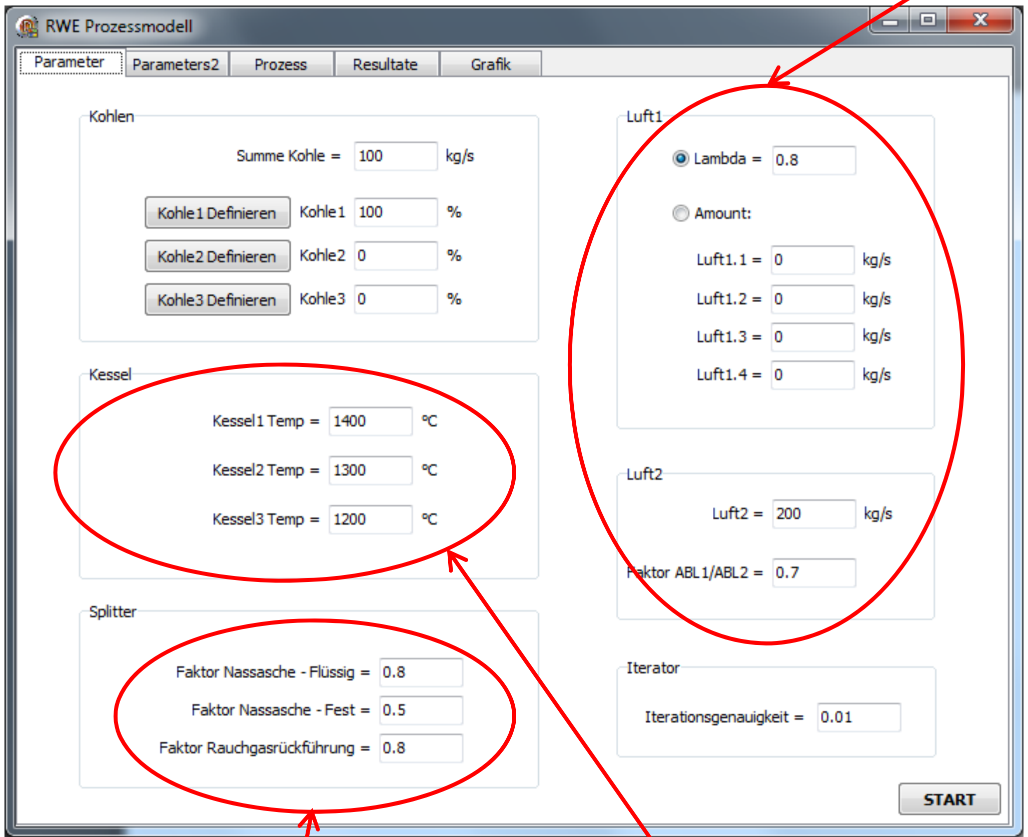
Kessel = Boiler

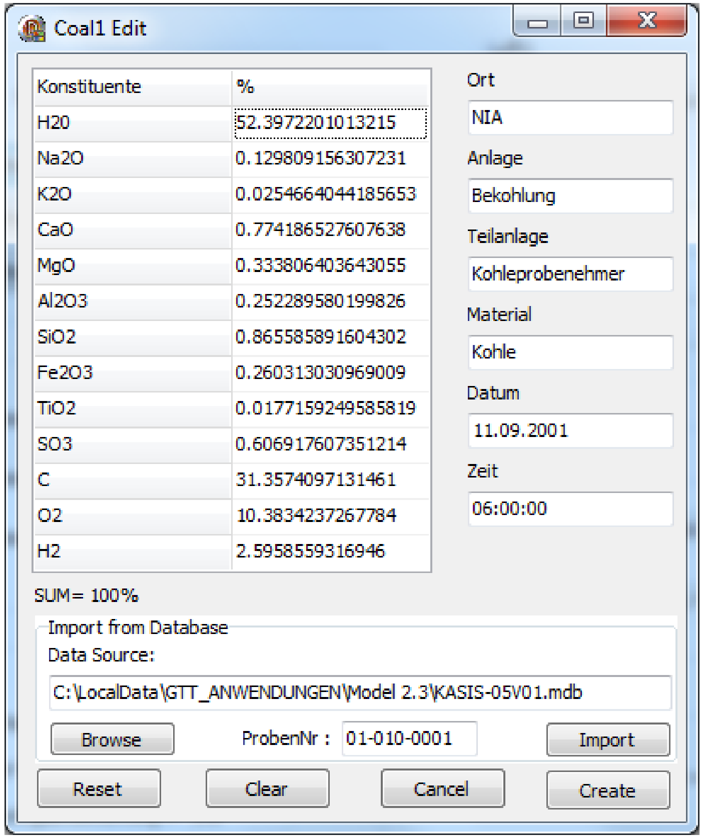
Luft = Air

NOTE: Model ends at upper end of combustion chamber

Furnace chamber model: User interface I

Air supply:
On average or partitioned in four areas





Proportion of fluid / solid wet ash
Proportion of flue gas recirculation

Temperatur in combustion chamber partitioned in three areas

Furnace chamber model: Results I

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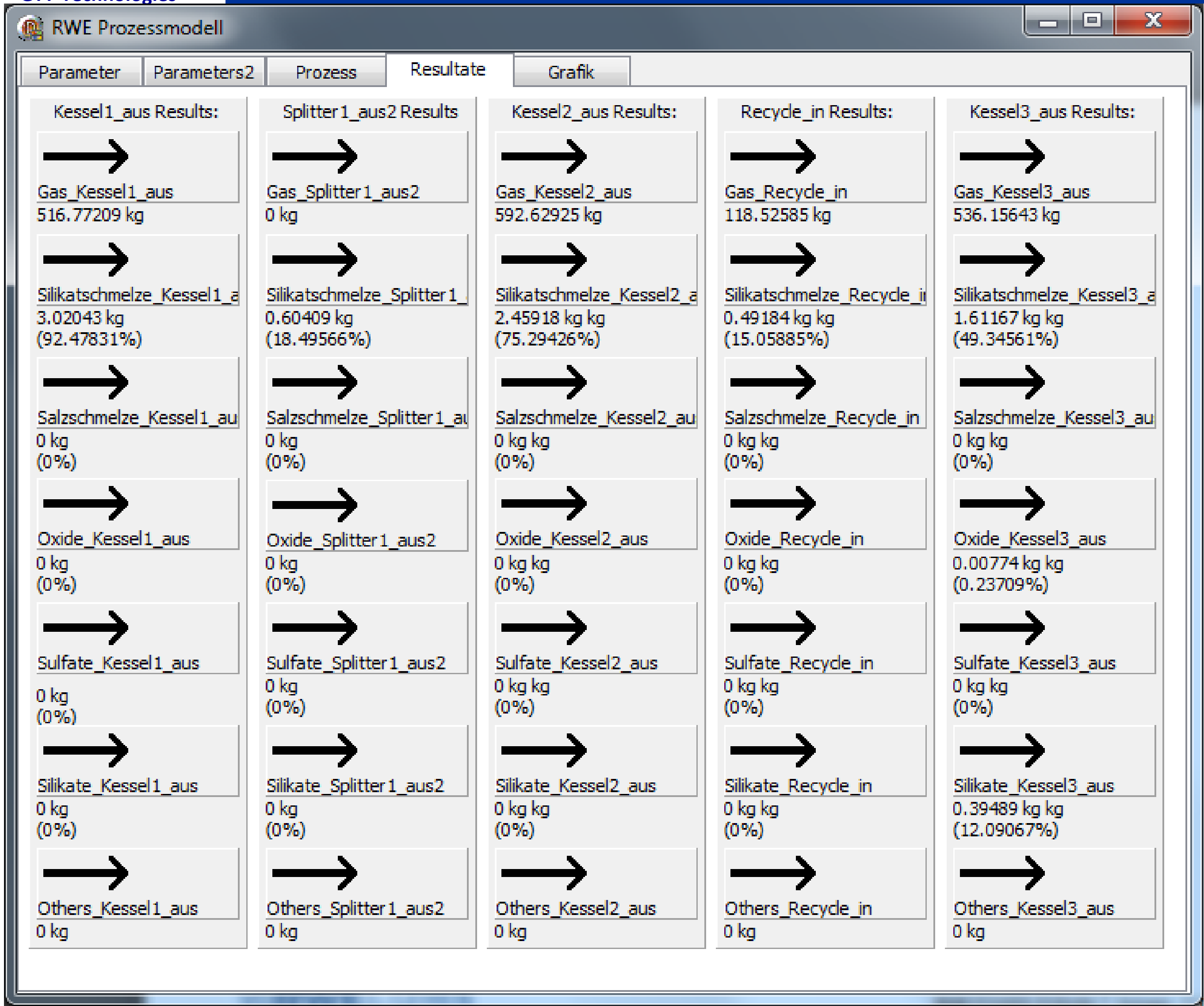

Phases are compiled in characteristic groups:

Silicate melt
Salt melt
Solid oxides
Solid sulphates
others

Furnace chamber model: Results IIa
Influence of coal blends on phase formation

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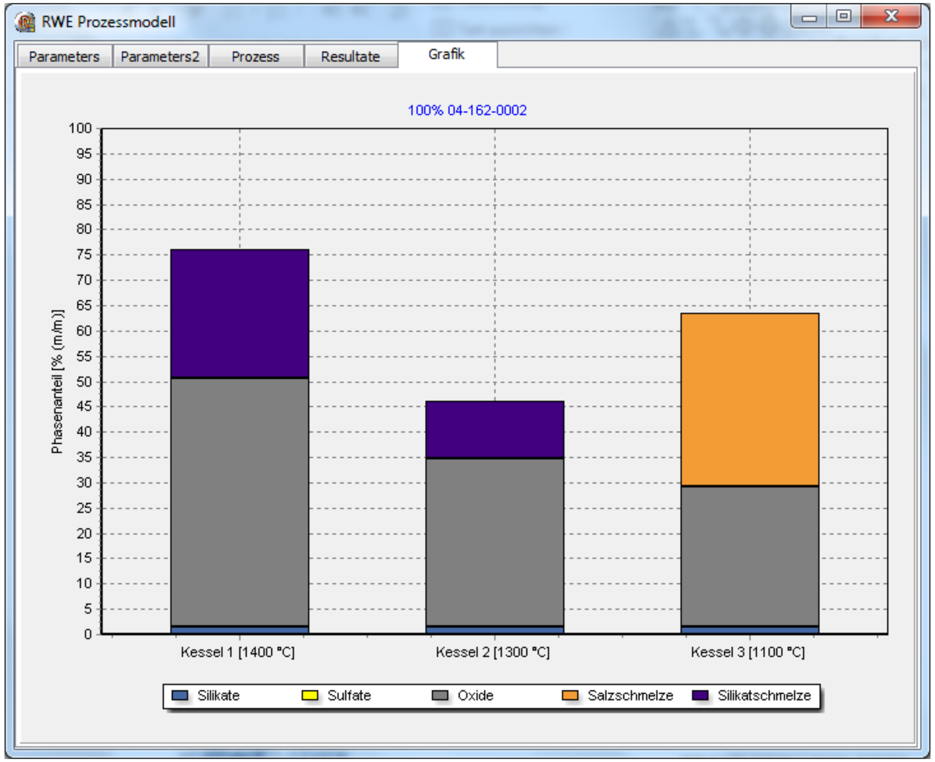
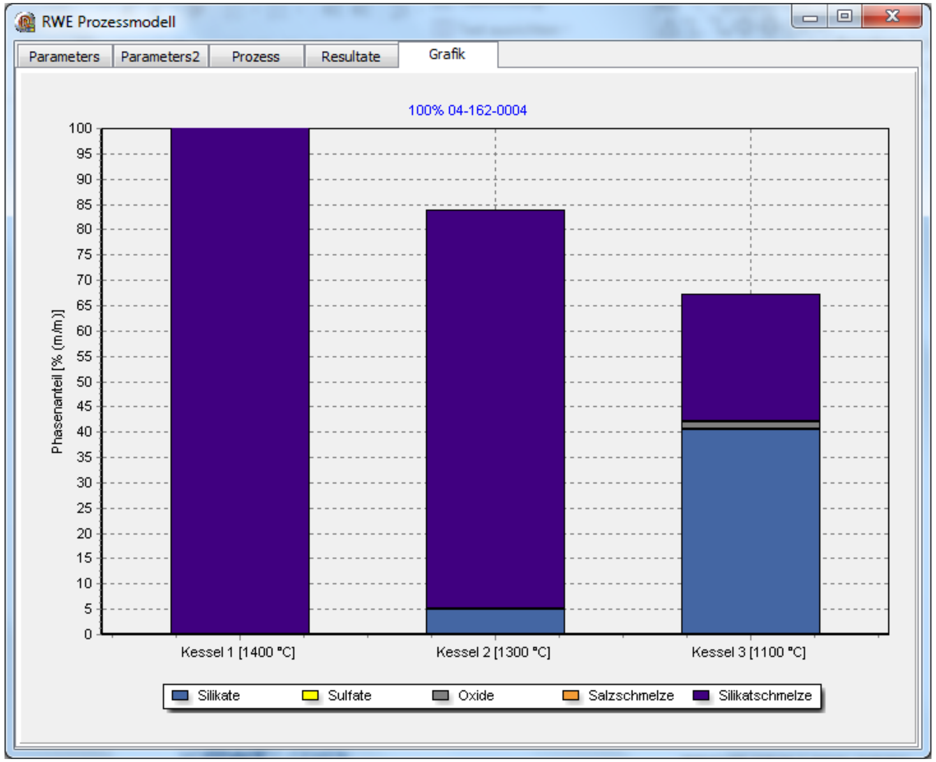
100% HKN



100% HKT



Furnace chamber model: Results IIb
Influence of coal blends on phase formation

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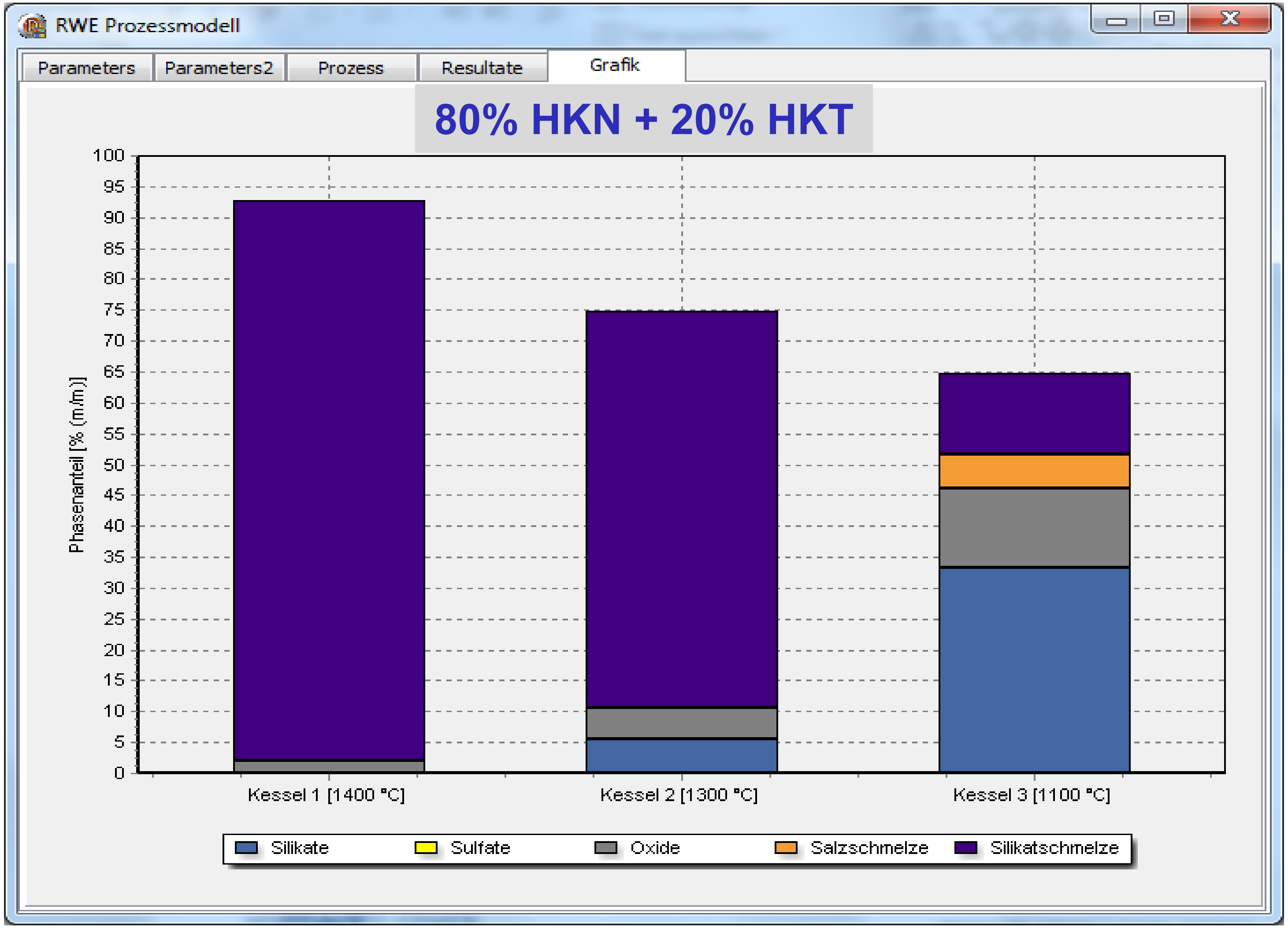
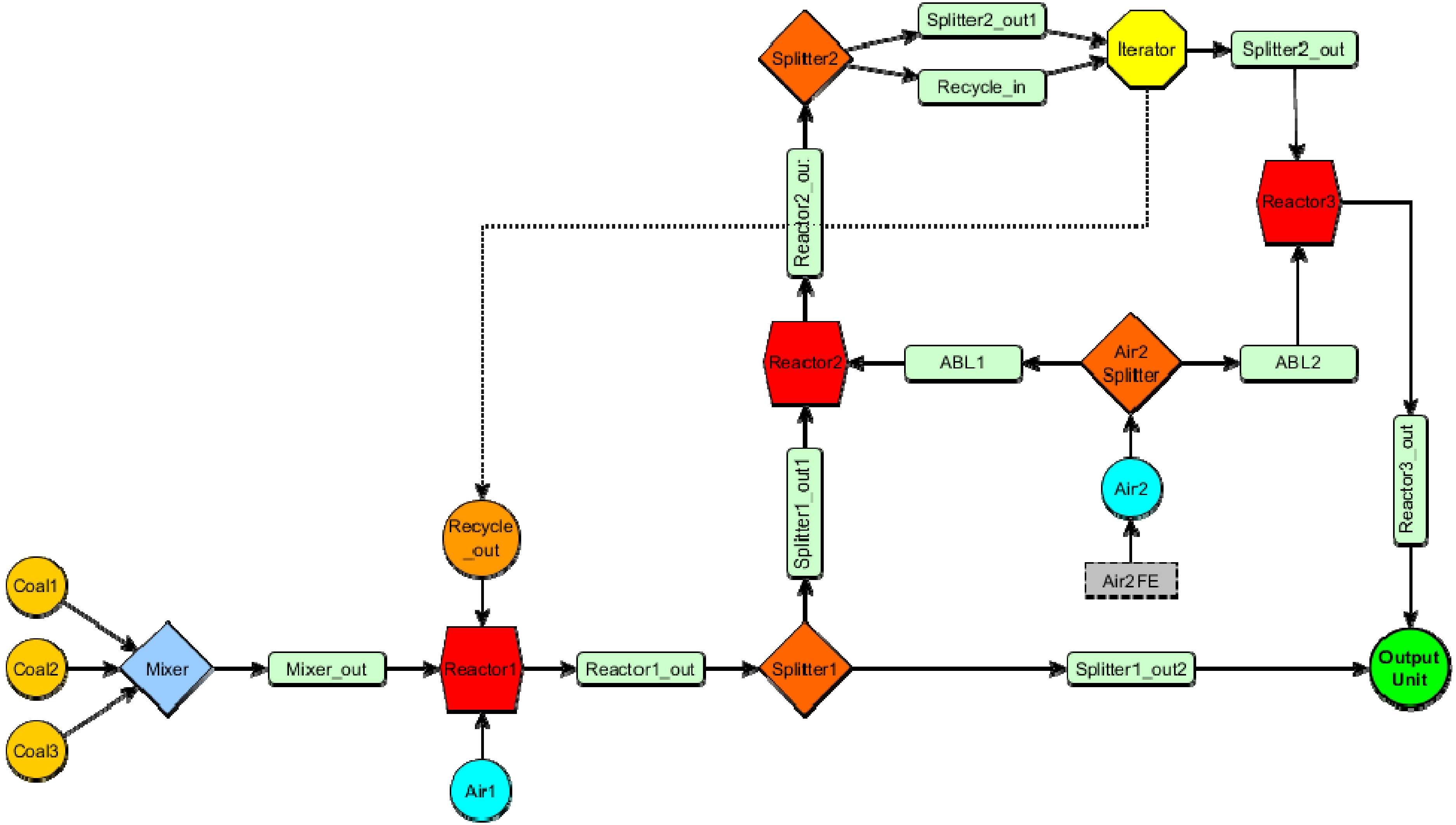
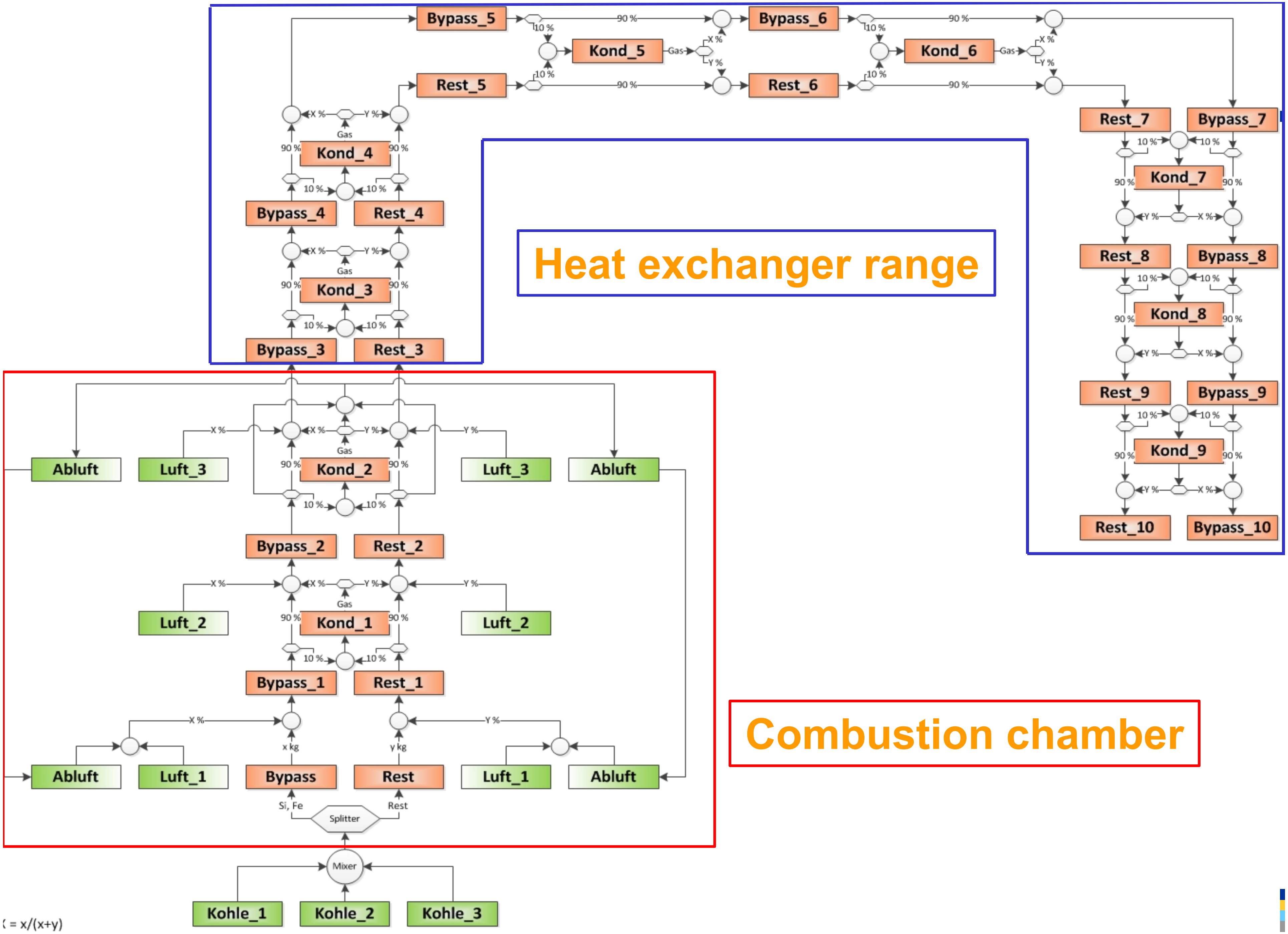


Scheme of the RWE model

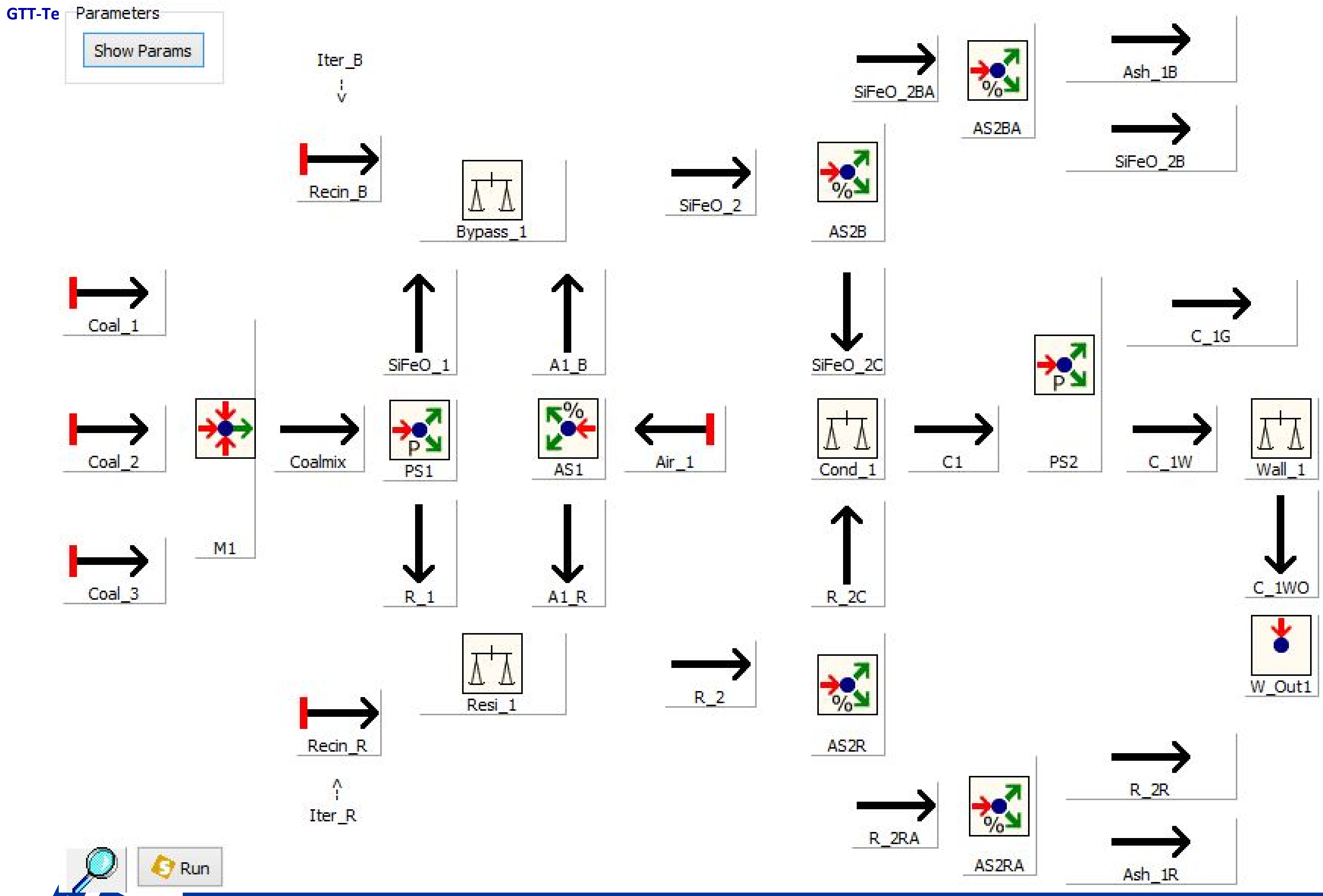




Heat exchanger range
Combustion chamber
Bypass_5
Bypass_6
Kond_5
Kond_6
Rest_5
Rest_6
Rest_7
Bypass_7
Kond_7
Rest_8
Bypass_8
Kond_8
Rest_9
Bypass_9
Kond_9
Rest_10
Bypass_10
Kond_4
Bypass_4
Rest_4
Kond_3
Bypass_3
Rest_3
Abluft
Luft_3
Kond_2
Bypass_2
Rest_2
Luft_2
Kond_1
Bypass_1
Rest_1
Luft_1
Bypass
Rest
Splitter
Si, Fe
x kg
y kg
Mixer
Kohle_1
Kohle_2
Kohle_3
Gas
X %
Y %
10 %
90 %

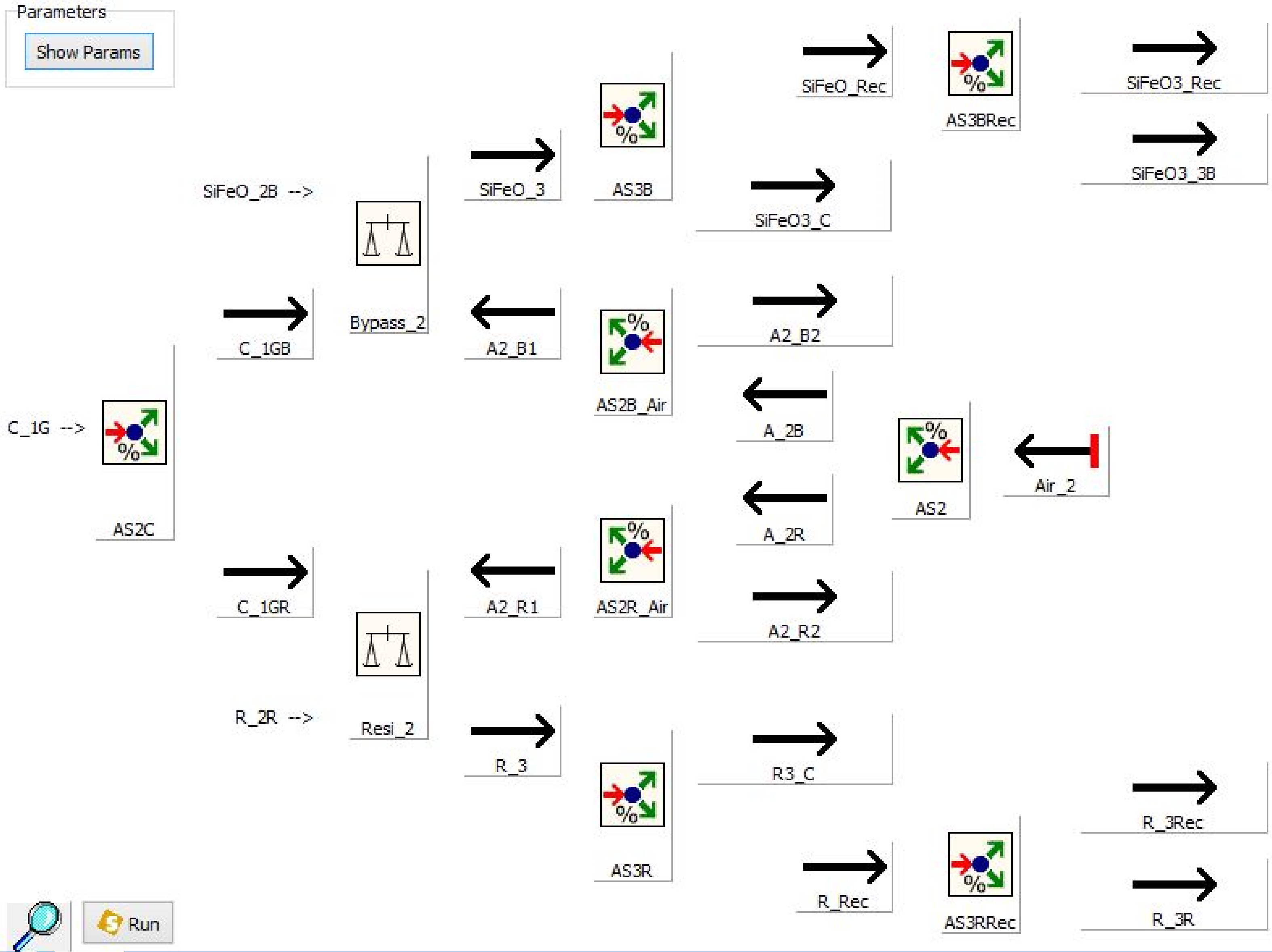
= x/(x+y)
= y/(x+y)

Realisation with SimuSage, Part 1

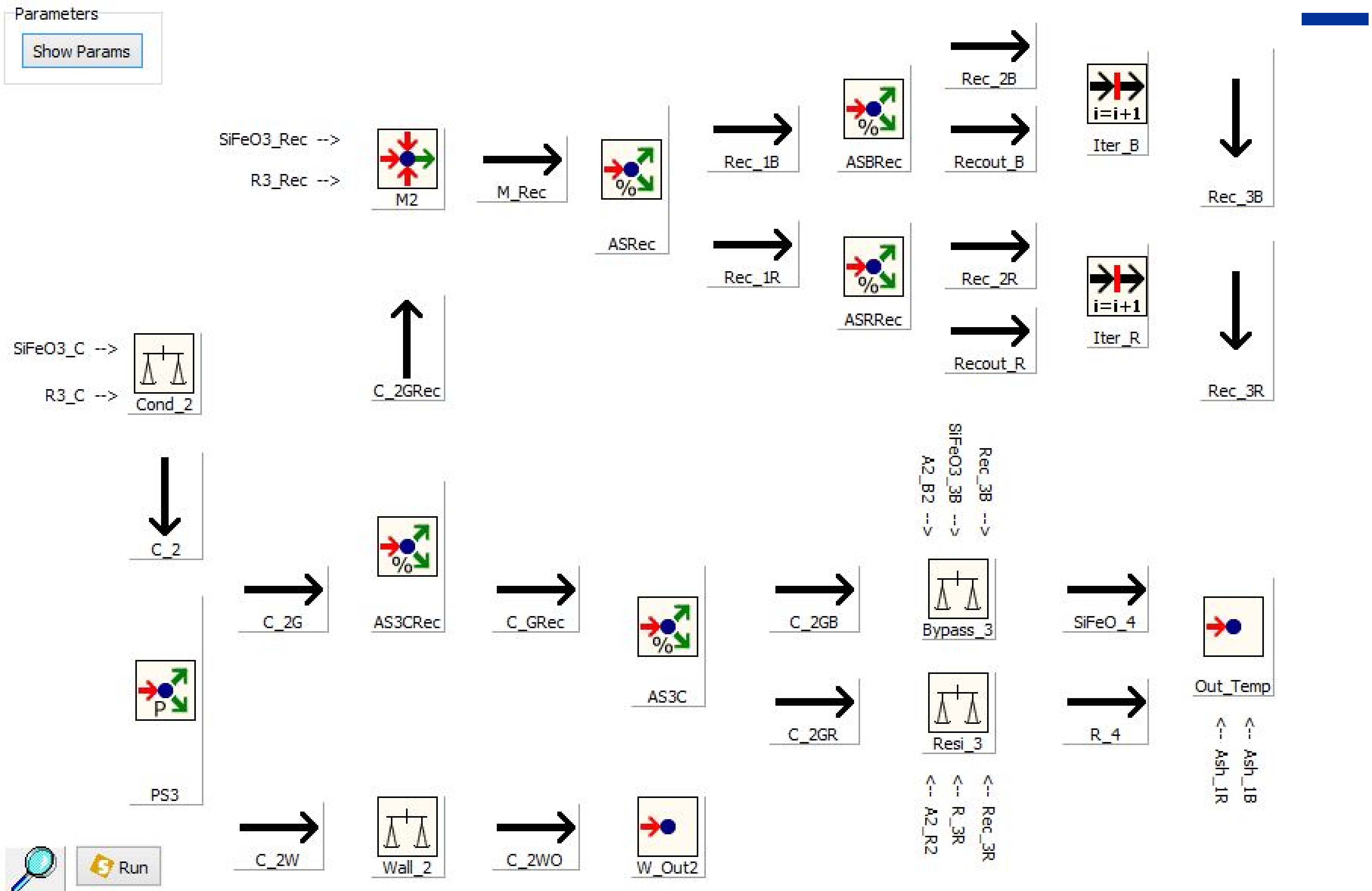


Realisation with SimuSage, Part 2

GTT-Tec



Realisation with SimuSage, Part 2



Test of model compatibility

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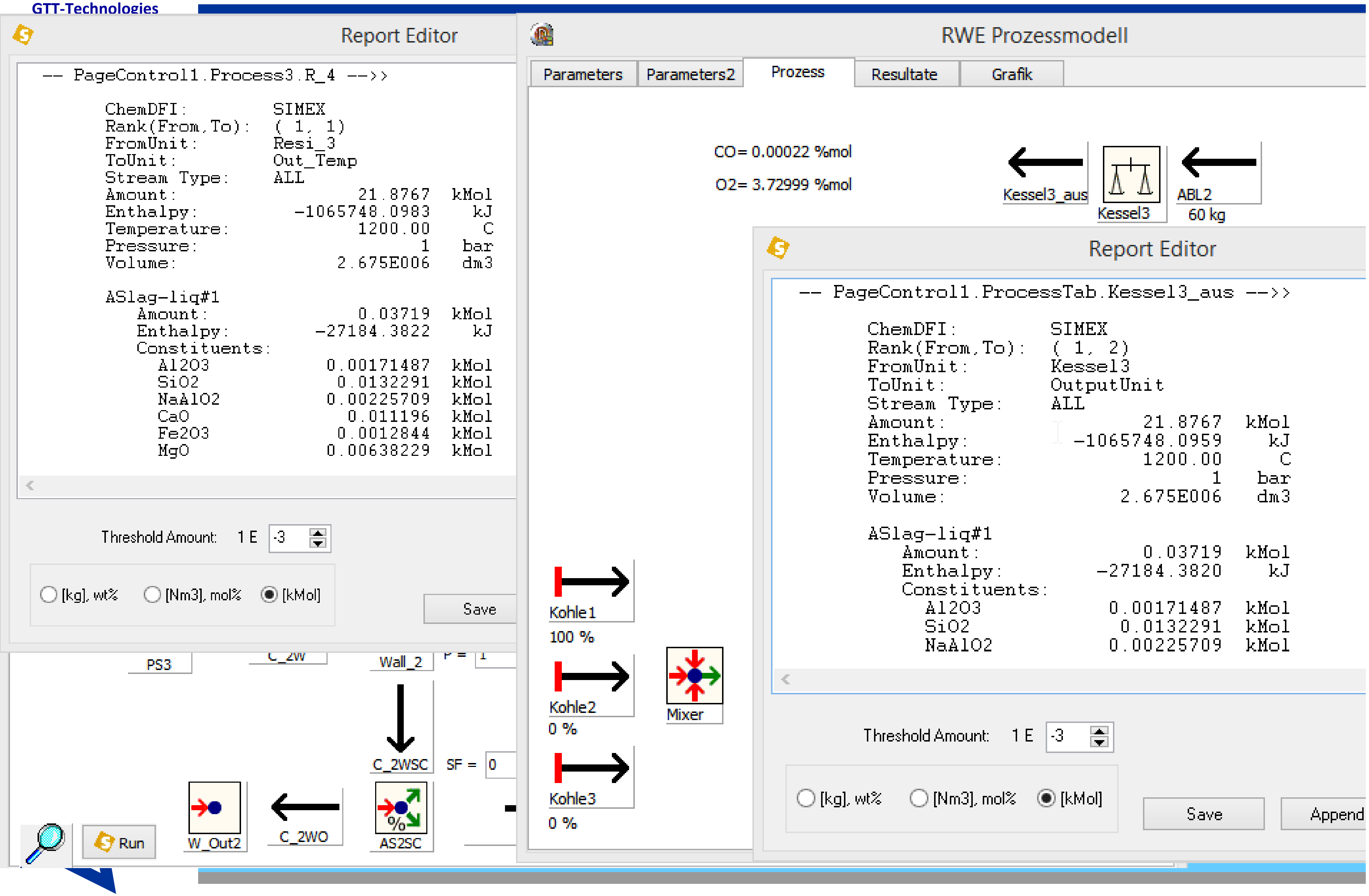

State of development

- First test: re-produce RWE model by appropriate choice of split factors

  → All numerical values agree 1:1 !!!

- Now in progress: run model with split factors realising no wall-sticking and no silicate by-pass, i.e. extend RWE-model by stages related to heat exchangers
- Next step: include silicate by-pass
- Then: include wall-sticking

Summary and Outlook

SimuSage based model using interlinked local equilibria

→ Furnace chamber model with interactive user interface and direct access to RWE mineral analyses database

→ First step into development of a proper process model for coal fired power plant

→ Furnace chamber with recirculation of flue gas and input option for coal blends

→ To come: *Optimisation* calculations for coal blends as well as *extension into boiler range* and *deposit modelling*

(→VerSi project)

THANK YOU VERY MUCH FOR YOUR ATTENTION !