Application of FactSage and SimuSage calculations in research and education within Process Metallurgy at Luleå University of Technology

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Outline

- Earlier activities on process modelling
- Research within Process Metallurgy at LTU
- Process modelling of a copper converter
- Leaching from steelmaking slag
- Application of slag in cement applications
- Conclusions

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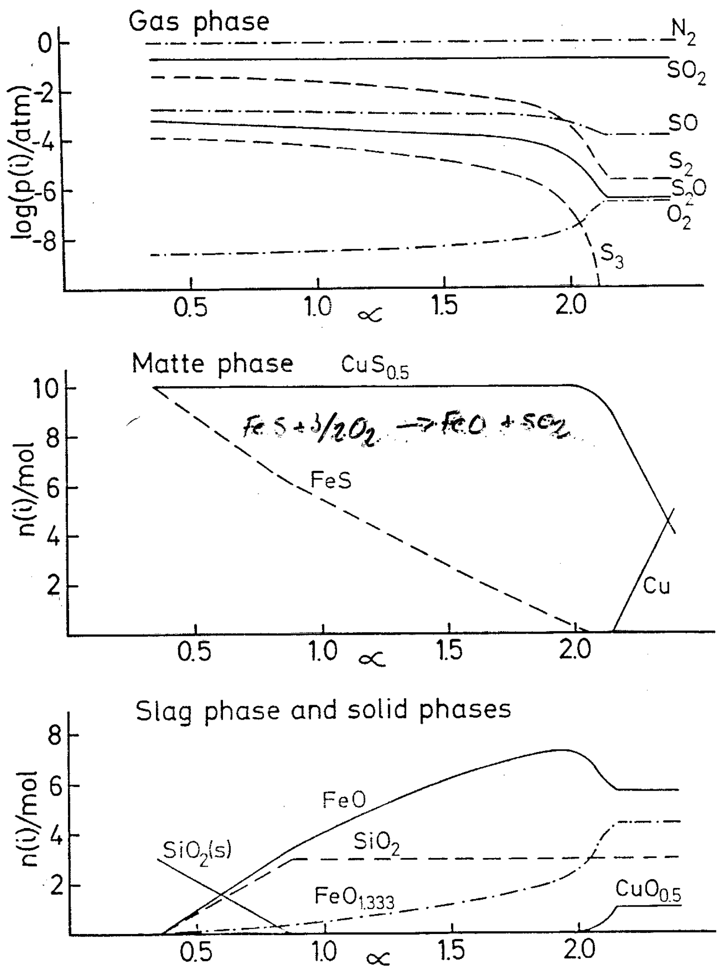
- Supervisor during PhD study
- Teacher in thermodynamics
- Introduced me to SOLGASMIX
- Good friend

Thank You and the very best for the future!


Use of Solgasmix in the 80´s

Calculations on smelting and converting of copper



Björkman B, Eriksson G, Quantitative Equilibrium Calculations on Conventional Copper Smelting and Converting, Can. Metall. Q., 21, 1982, 329-37.

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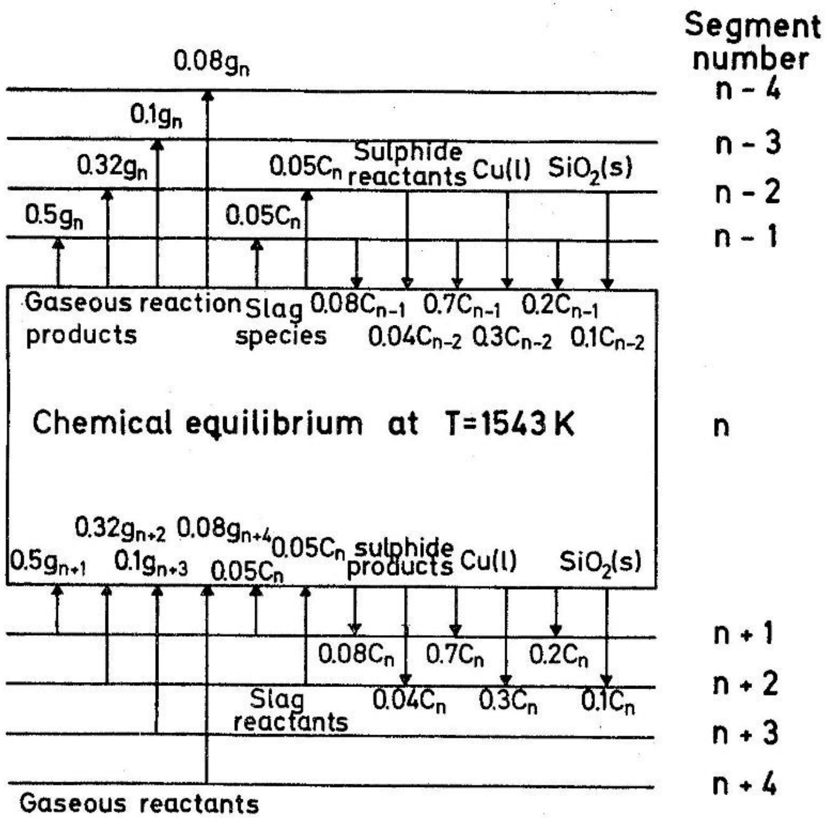
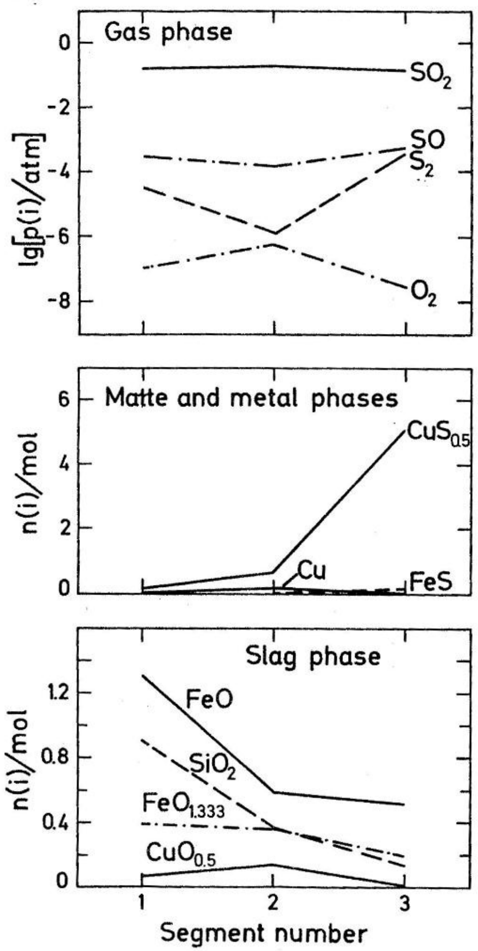




Björkman, B, Quantitative equilibrium calculations with relevance to copper making, Thesis, Umeå University, 1984, Supervisors Gunnar Eriksson and Erik Rosén

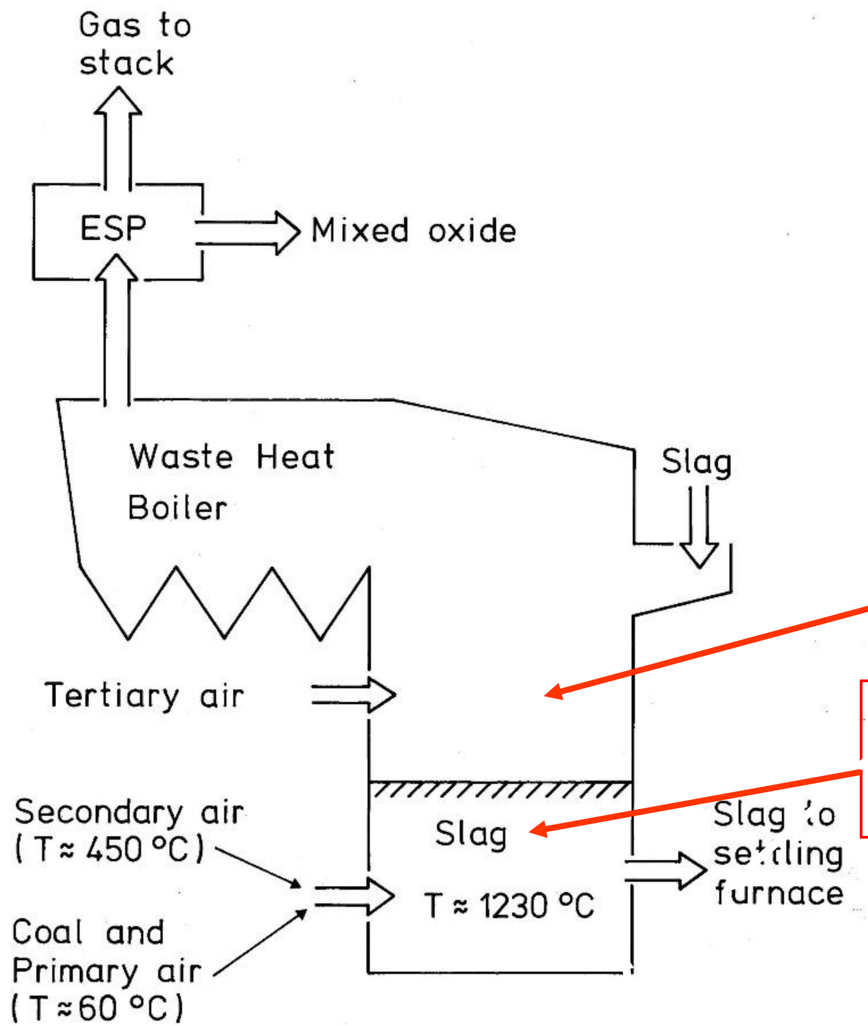
Process simulations during 80´s at Boliden and at LTU.

A simple data file for the system *Cu*-Fe-O-S-Zn-Pb-Ni-As-Sb-Bi-Sn-Ag-CaO-SiO_2-Al_2O_3-(Cl-C), including solution models for slag, matte and liquid metal phases.

Applied to:

- **Roasting of copper concentrates**
- **Calcualtions on chlorinating roasting**
- **Simulation of zinc fuming plant**
- **Smelting of copper containing scrap in a Kaldo furnace (TBRC)**
- **Smelting and converting of anode slime in a Kaldo furnace (TBRC)**
- **Gas composition during copper converting**
- **Impurity distribution during smelting and converting**

Example:
Dust formation in the zinc fuming plant at Boliden AB, Rönnskärsverken



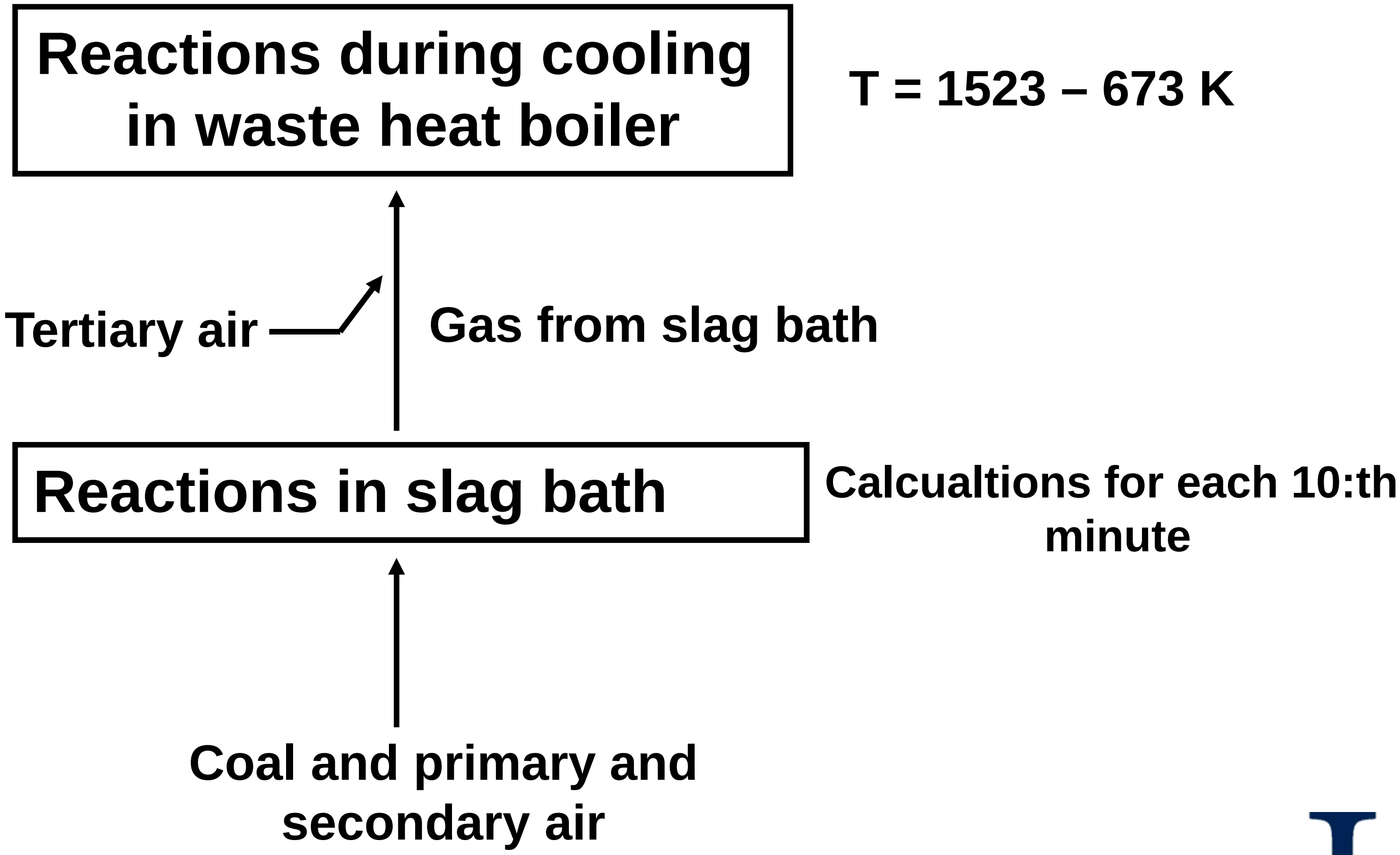
$$2Zn(g) + O_2 \longrightarrow 2\ ZnO$$

$$2CO + O_2 \longrightarrow 2CO_2$$

$$CO(g) + ZnO\ (sl) \rightarrow Zn(g) + CO_2(g)$$

$$2\ C + CO_2(g) \longrightarrow 2\ CO(g)$$

Calculation procedure



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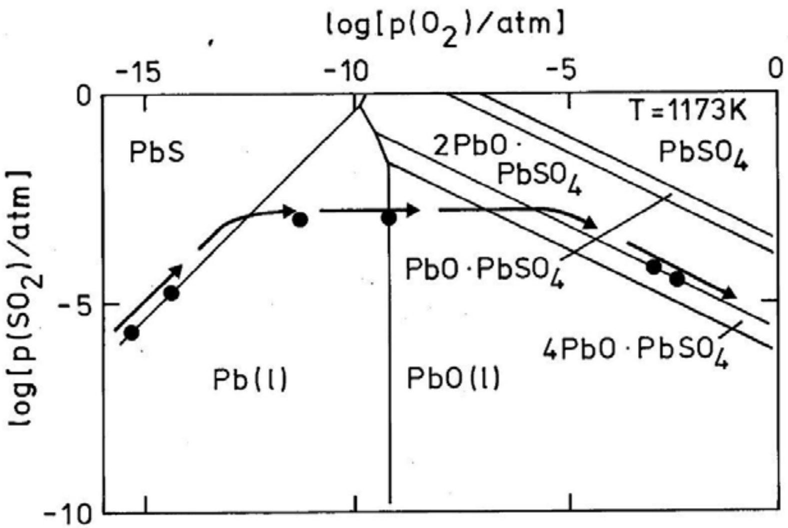
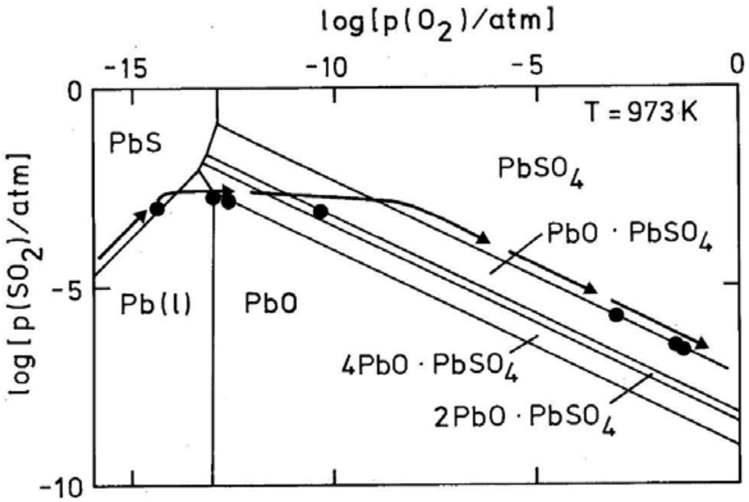
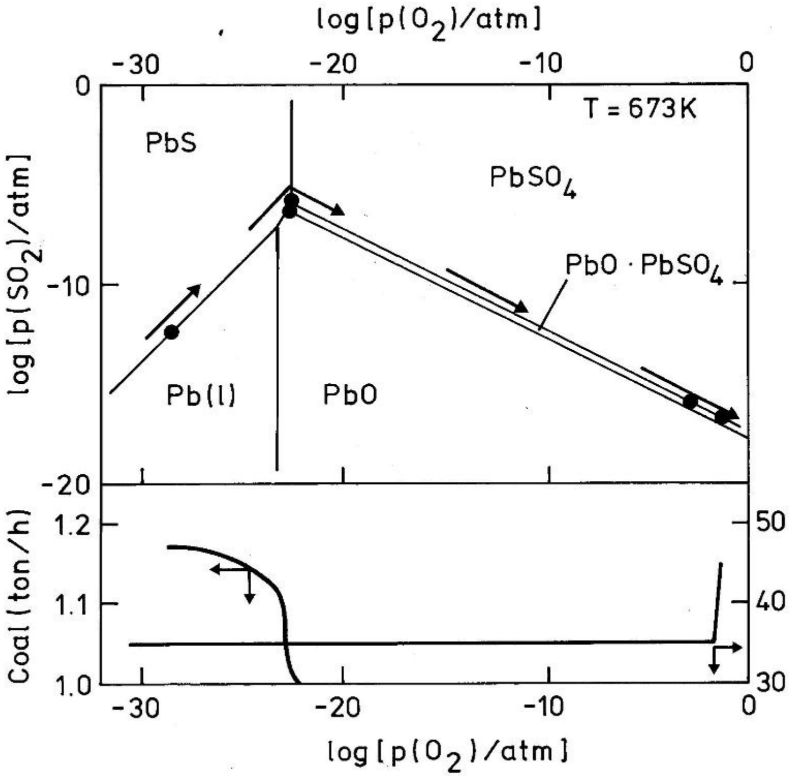
Results on formation of condensed lead phases during cooling of the process gas







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Research within Process Metallurgy at LTU

MiMeR, Minerals and Metals Research Laboratory:

Two research subjects: **Process Metallurgy** **Mineral Processing**

Six full professors:

Process Metallurgy	**Mineral Processing**	**Surface chemistry**
Hydrometallurgy	**Sustainable Production of Iron Ore**	**GeoMetallurgy**

Application Areas related to Process Metallurgy:

Base metals production **Iron making** **Bio-hydrometallurgy**

Recycling and Residue utilisation

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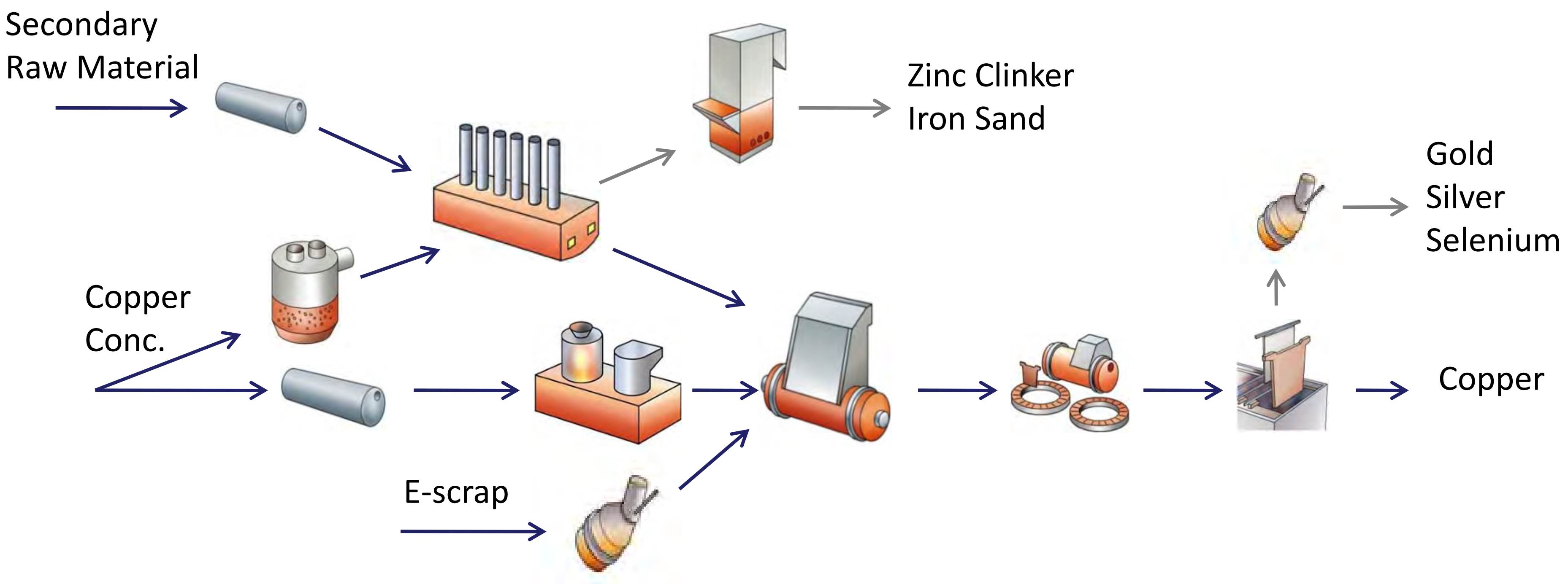
Simulations connected to a PS-copper converter

Copper flow at Bolidens Rönnskär smelter



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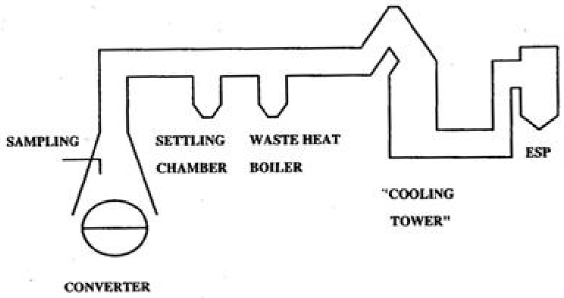
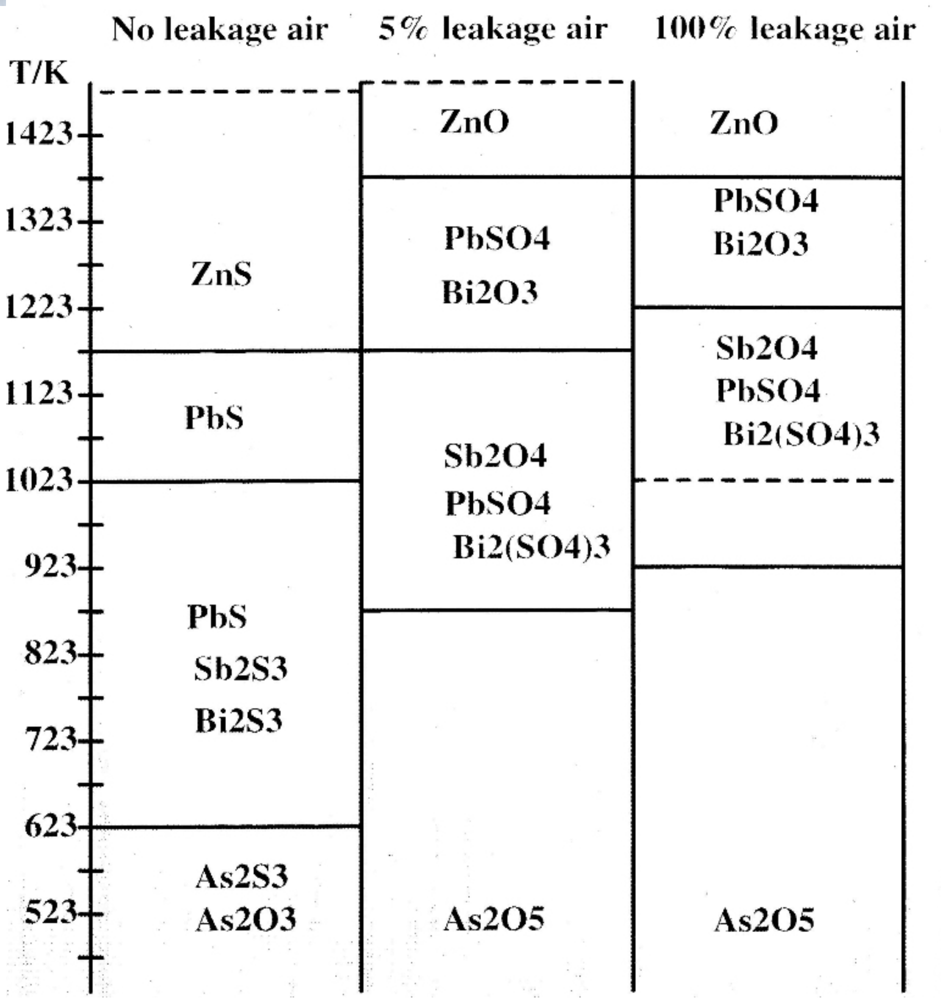
Simulation of dust formation in the dust cleaning system of a PS-Converter



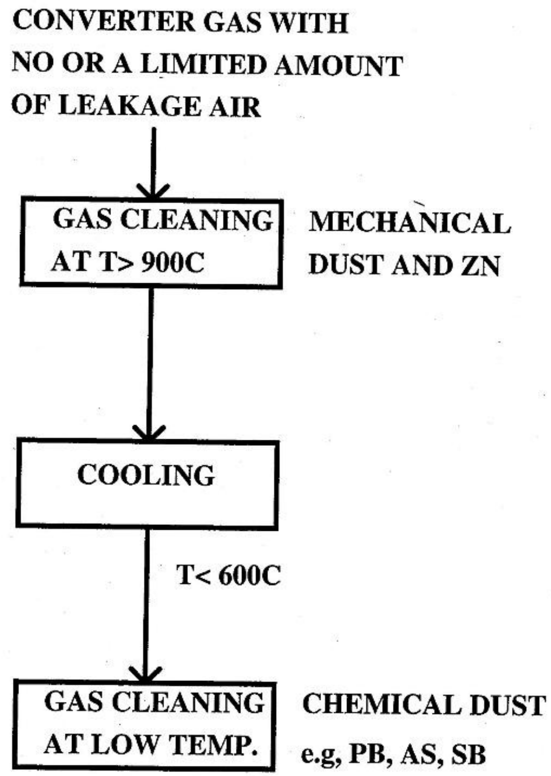
AVERAGE COMPOSITION OF DUST, FIGURES GIVEN IN WEIGHT%

	CONVERTER HOOD, FINE FRACTION	SETTLING CHAMBER	WASTE HEAT BOILER	COOLING TOWER	ESP
Cu	1	26	22	22	0.8
Fe	0.4	3	2	3	0.2
SiO_2	-	31	38	15	0.7
Pb	42	4	15	16	42
Zn	11	2	5	6	10
As	4	0.25	1	2	6.5
Bi	1	0.08	0.5	0.5	1.5
S	8	8	10	12	9

Condensation from gas versus amount of leakage air at equilibrium conditions



POSSIBILITIES TO OBTAIN A CONTROLLED DUST GENERATION



Challenges in modelling a P.S. Converter

<u>Charactherised by:</u>

Non-ideal behavior

Non-equilibrium process

Minor elements not assessed for the system

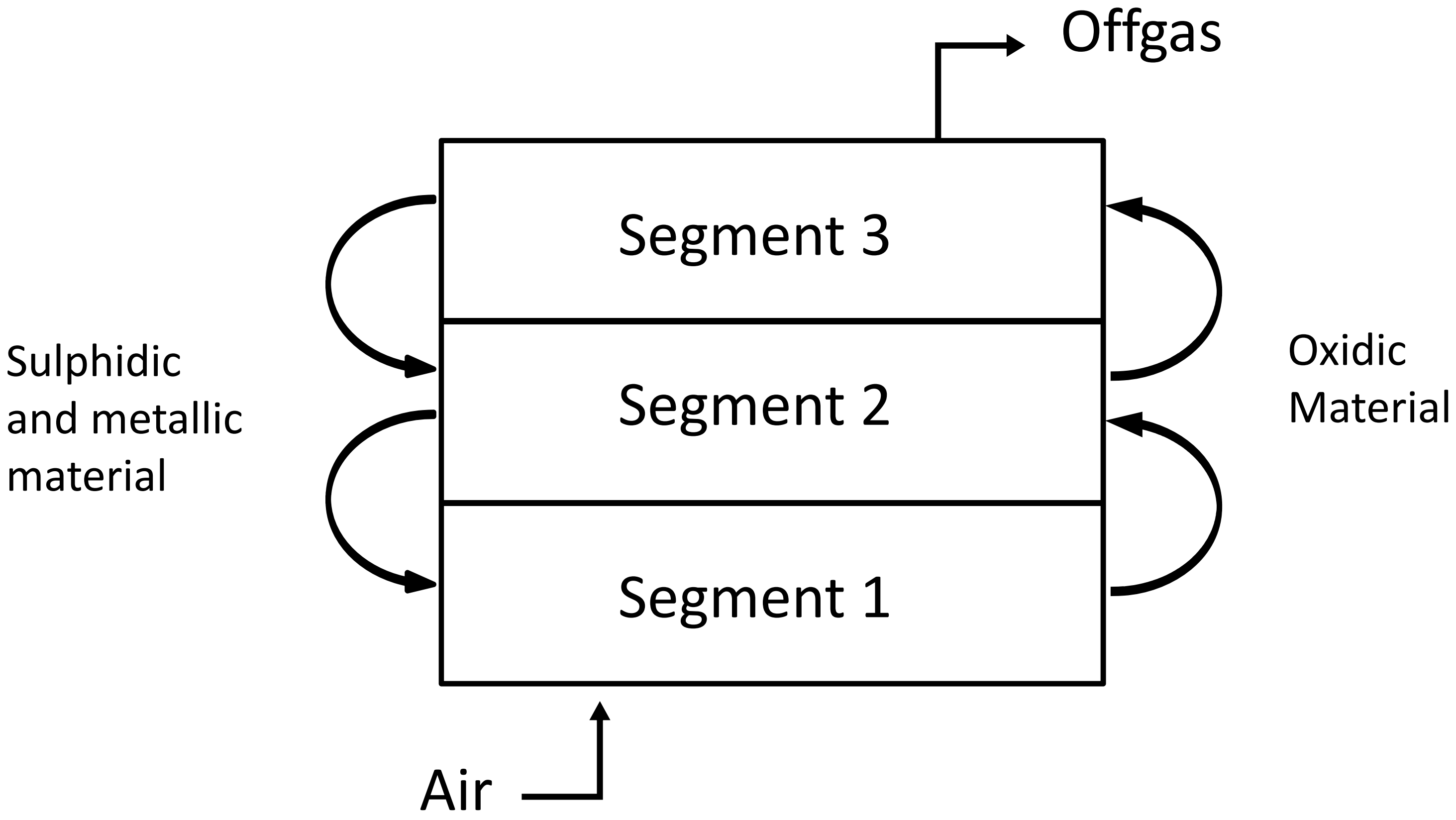
More than obvious phases (e.g. several mattes, immiscible slags, dispersions)

<u>Challanges</u>

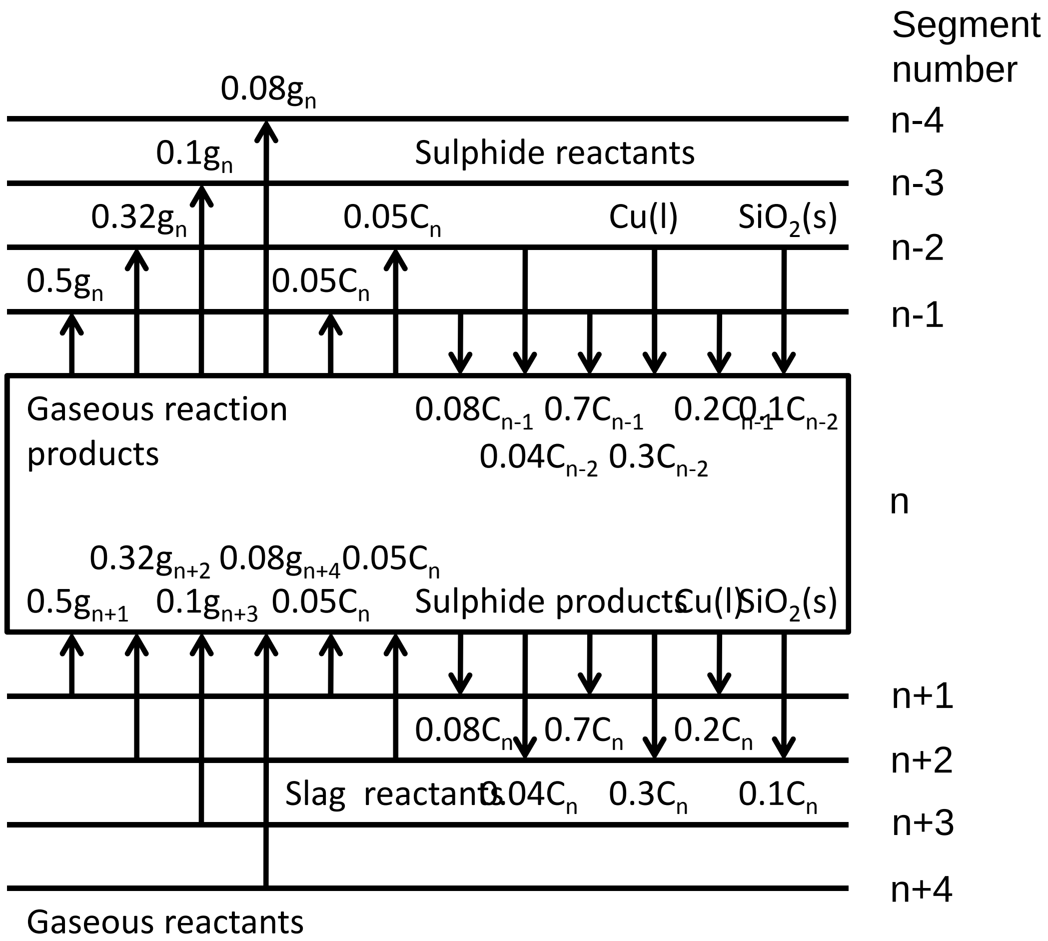
How to include non-equilibrium

Include minor elements to liquid sulphide, slag and liquid metal

Include Non-equilibrium



Include Non-equilibrium



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Some comparisons between plant data and calculaled values – the slag composition

		Liquid slag					
		Fe	Cu	Pb	Zn	S	SiO2
Charge	Plant data	31.2	6.1	6.5	6.6	-	29.9
860	Model prediction	34.4	5.0	4.0	9.5	0.0	30.0
Charge	Plant data	30.4	7.9	7.9	5.2	0.5	30.8
864	Model prediction	29.8	7.4	10.5	5.5	0.0	31.9

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The white metal

		White metal				
		Fe	Cu	Pb	Zn	S
Charge	Plant data	0.4	75.9	0.5	0.1	17.8
860	Model prediction	1.1	75.9	1.7	0.6	20.0
Charge	Plant data	0.3	75.9	0.6	0.1	17.7
864	Model prediction	1.0	75.9	1.8	0.7	19.8

Conclusion from modelling of PS-converter

- **The complexity of scrap like WEEE and residue materials calls for new better process models.**
- **By introducing reactor segments into the model, the**

  non-equilibrium conditions can be simulated.
- **Need for better thermodynamic description for minor and micro elements in the system.**

Leaching from steelmaking slag - Water granulation

<u>Hypothesis</u>
Fast cooling -> formation of a glass -> enclosing the metals

Reactivity increases in most cases!

	LD slag			EAF slag		
Element	α Semi-rapid cooling	α Rapid cooling	(Rapid)/(Semi) %	α Semi-rapid cooling	α Rapid cooling	(Rapid)/(Semi) %
Ca	1,87E+00	9,86E+00	526%	2,90E-01	2,69E+00	928%
Na	1,87E-03	2,89E-02	1543%	1,09E-03	3,09E-02	2824%
S	4,62E-03	1,06E-01	2305%	2,55E-03	1,52E-02	596%
Si	6,34E-03	2,98E-01	4694%	6,30E-02	7,78E-01	1235%
Al	8,15E-03	7,76E-03	95%	2,30E-03	1,61E-02	701%
Ba	1,75E-04	8,93E-04	510%	2,67E-04	4,05E-04	151%
Cr	3,29E-06	1,74E-04	5284%	3,68E-04	5,50E-03	1494%
Mn	4,23E-05	3,99E-05	94%	6,26E-06	5,23E-05	835%
Mo	2,79E-05	3,11E-04	1117%	4,82E-05	3,84E-04	797%
V	2,98E-04	3,67E-02	12317%	1,24E-03	1,79E-03	144%

Two examples of EAF slag

	Type 1 Low all.	Type 2 High all.
CaO	28.8	41.0
SiO_2	11.8	28.4
MgO	8.5	4.7
FeO	25.5	2.2
MnO	6.1	3.2
Al_2O_3	4.9	10.1
Cr_2O_3	3.5	5.7
Fe_{met}	4.8	0
B_2	2.4	1.4

Common minerals in EAF slags

Type 1

β-Ca_2SiO_4

$Ca_2Fe_2O_5$

FeO

MgO

Type 2

$Ca_3MgSi_2O_8$

$Ca_{14}Mg(SiO_4)_2$

AB_2O_4-spinel

Leaching of chromium might be a problem for the utilization of the slag!

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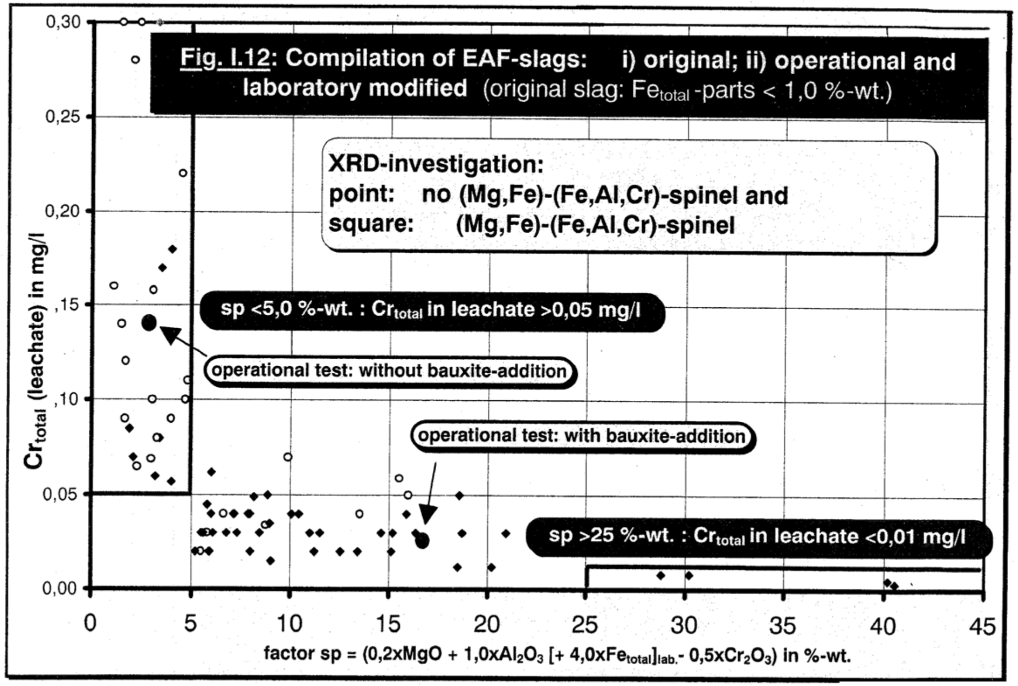
The spinell factor to describe leaching of Cr from steelmaking slag (FEhS ,Year 2000)

$$sp = 0.2MgO + 1.0Al_2O_3 + nFeOx - 0.5Cr_2O_3$$

n' is a number between 1 and 4, depending on the oxidation state of the slag.



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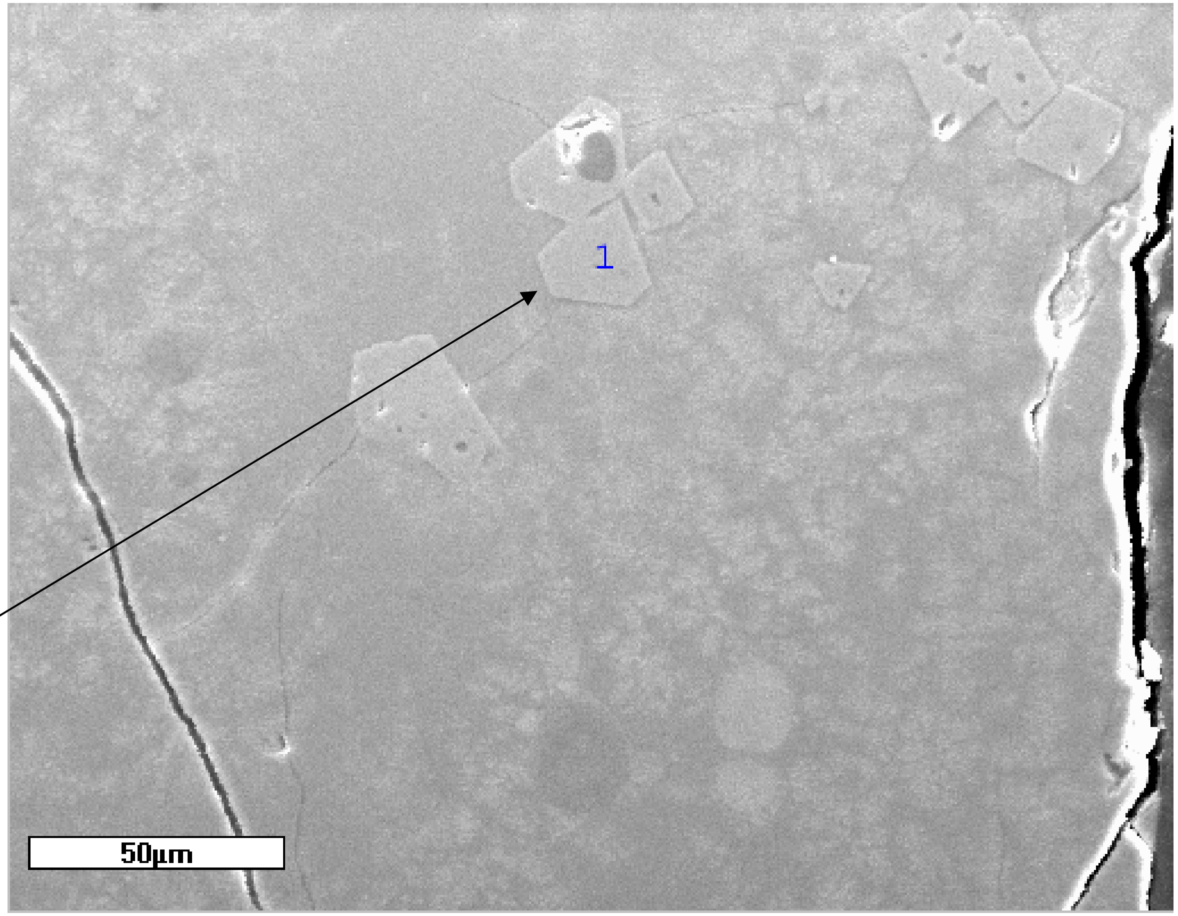
Chromium in EAF slag

<u>EAF slag type 1</u>

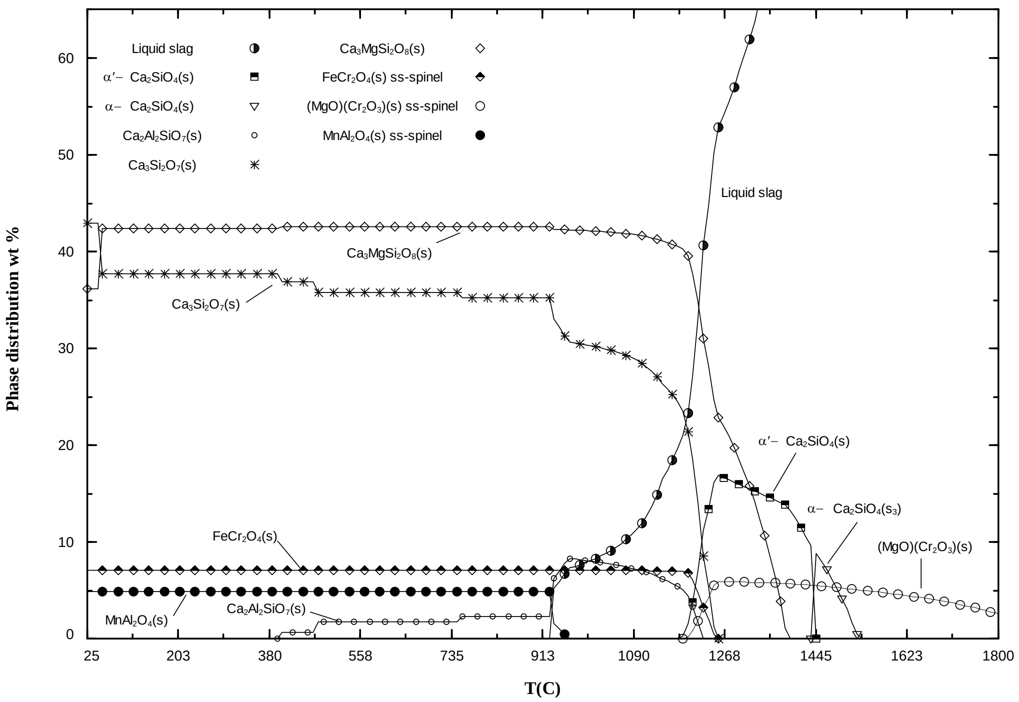
Sp-factor not working

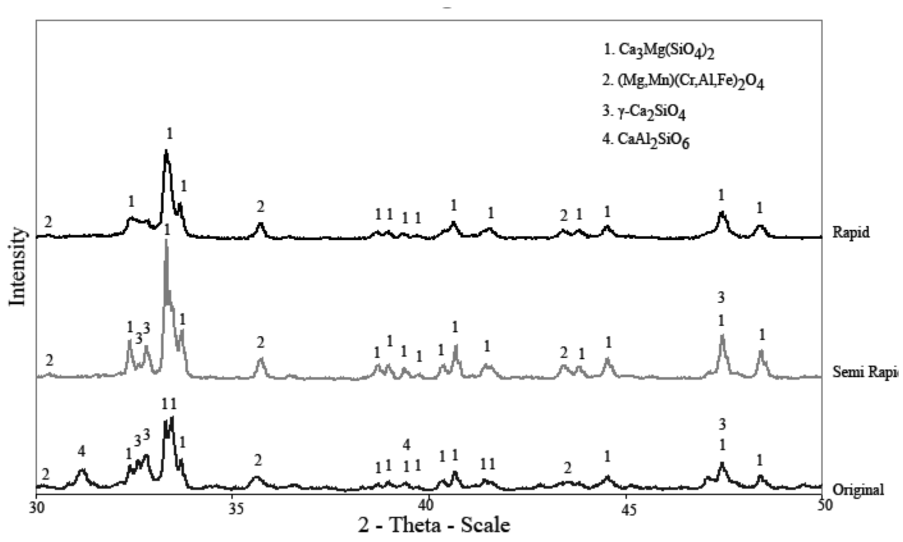
<u>EAF slag type 2</u>

Sp-factor working



EAF slag, type 2

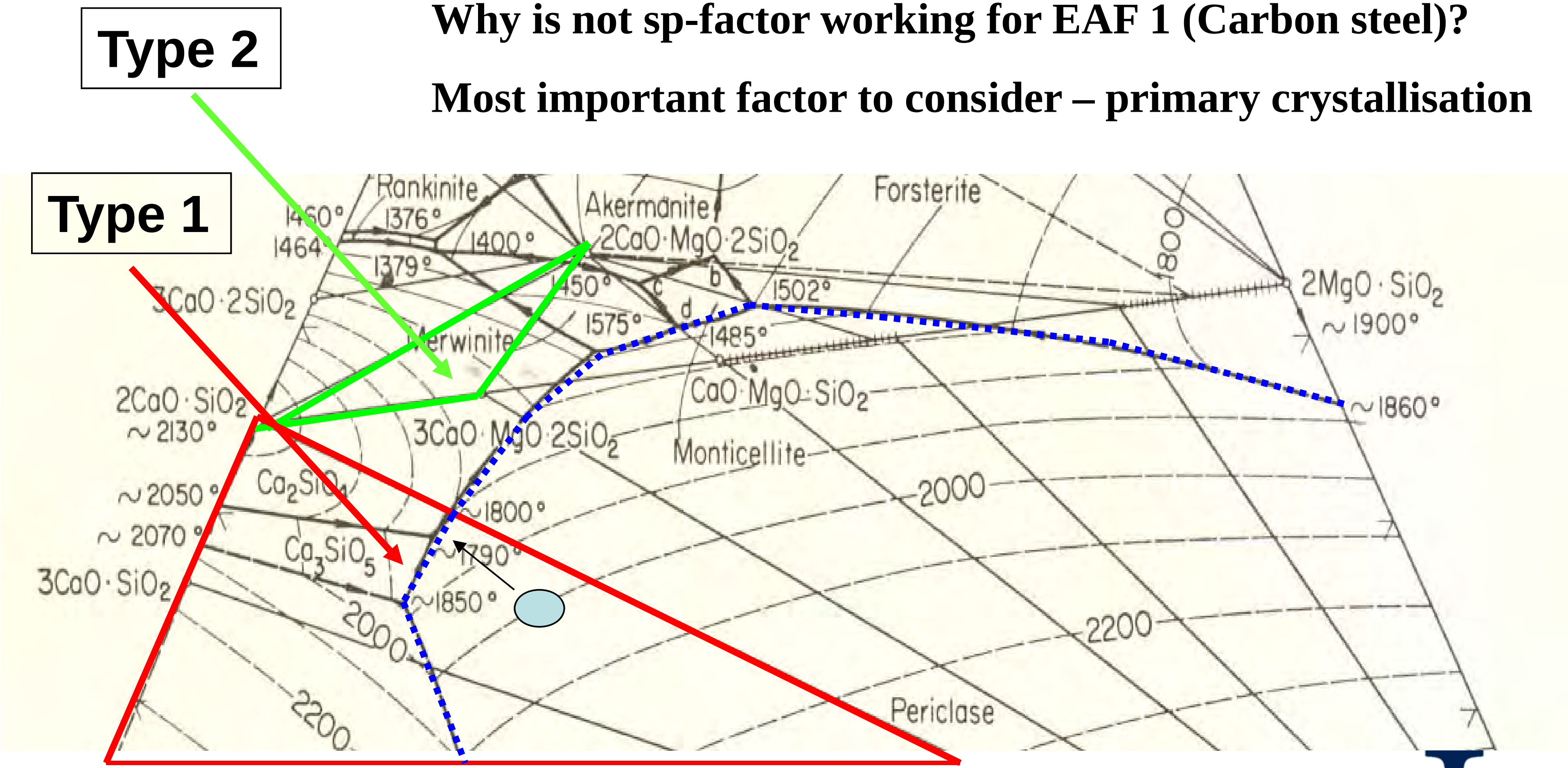




Chromium in EAF slag

Why is not sp-factor working for EAF 1 (Carbon steel)?

Most important factor to consider – primary crystallisation



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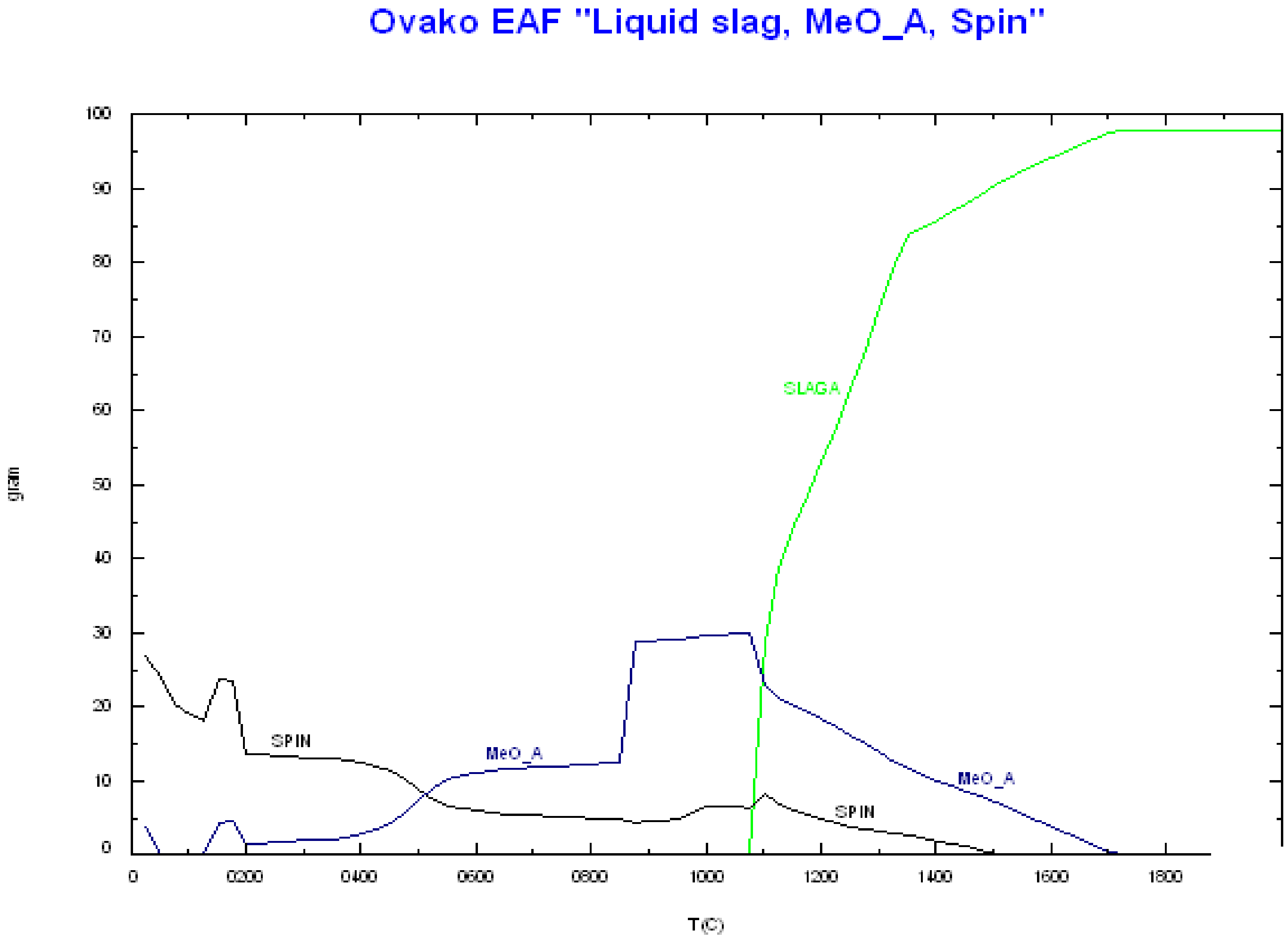
EAF slag, type 1



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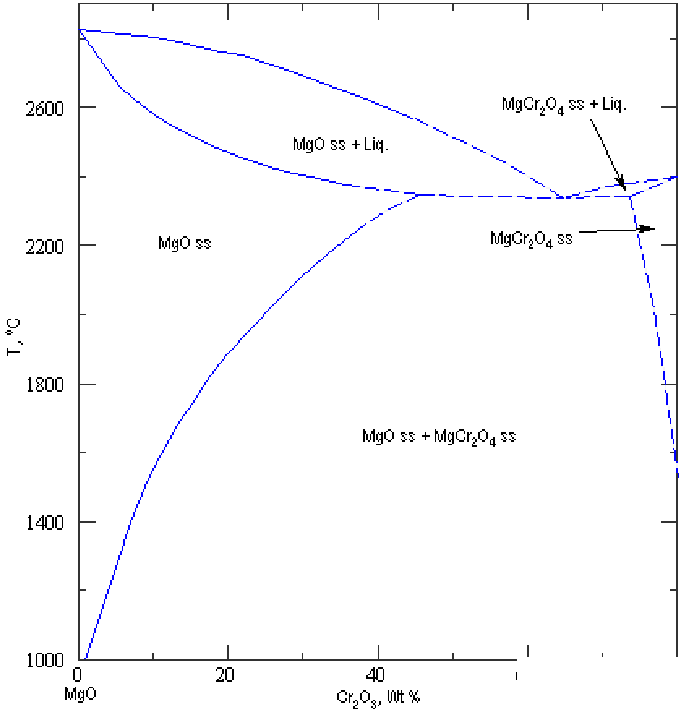
Chromium in EAF slag

EAF 1 (Carbon steel) MgO saturated
EAF 2 (Stainless) not MgO saturated

EAF 1

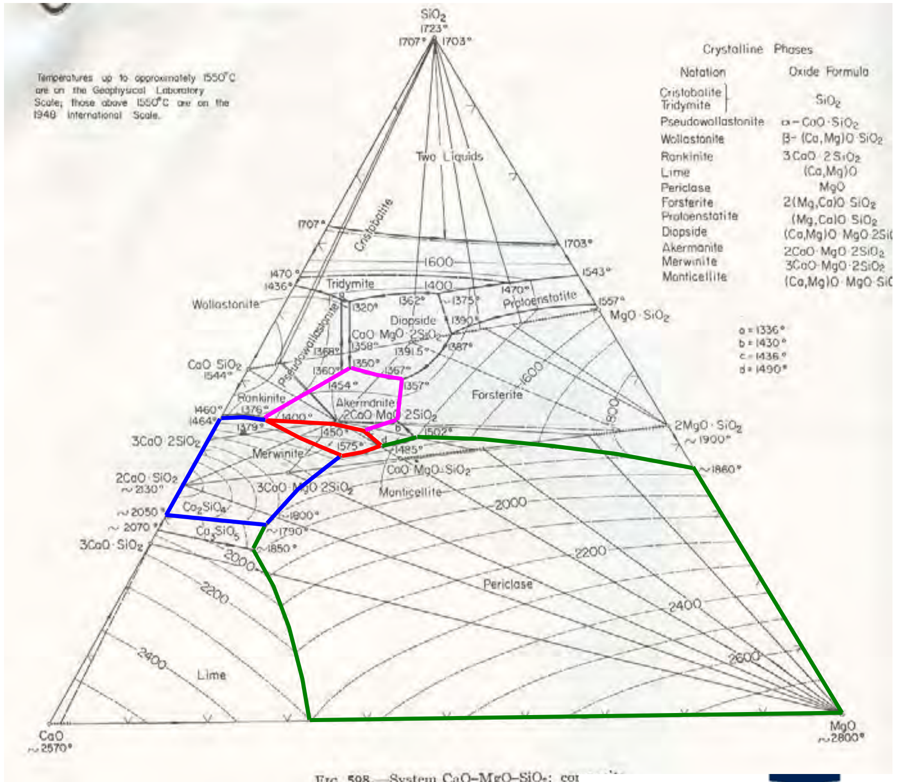
Cr will be enriched in MgO (ss) instead of forming spinel primary. MgO (ss) can dissolve up to ~ 40 wt%



Distribution of chromium

	Dissolves chromium
Merwinite	Yes
Akermanite	No
γ-Ca_2SiO_4	No
MgO	Yes
Gehlenit	No
$Ca_2Fe_2O_5$	Yes
$3CaO*Al_2O_3$	No

Totally 11 Cr containing slag minerals was found!



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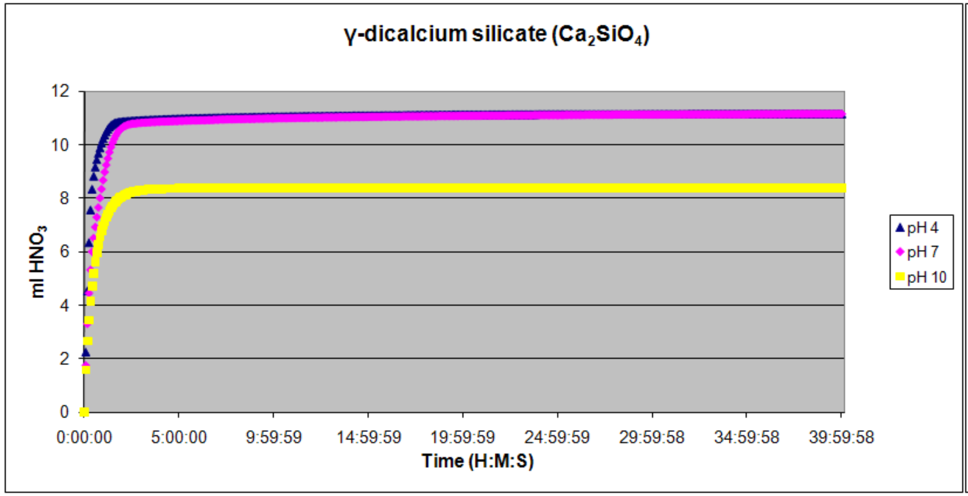
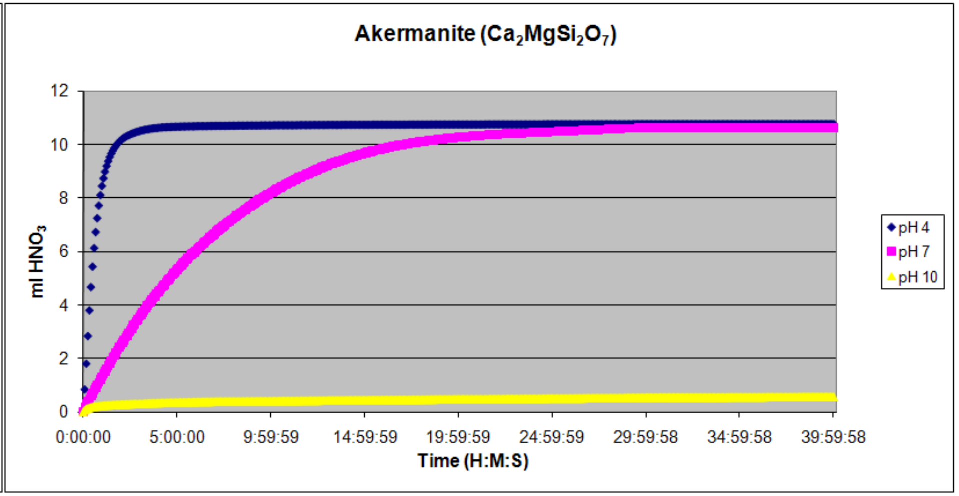
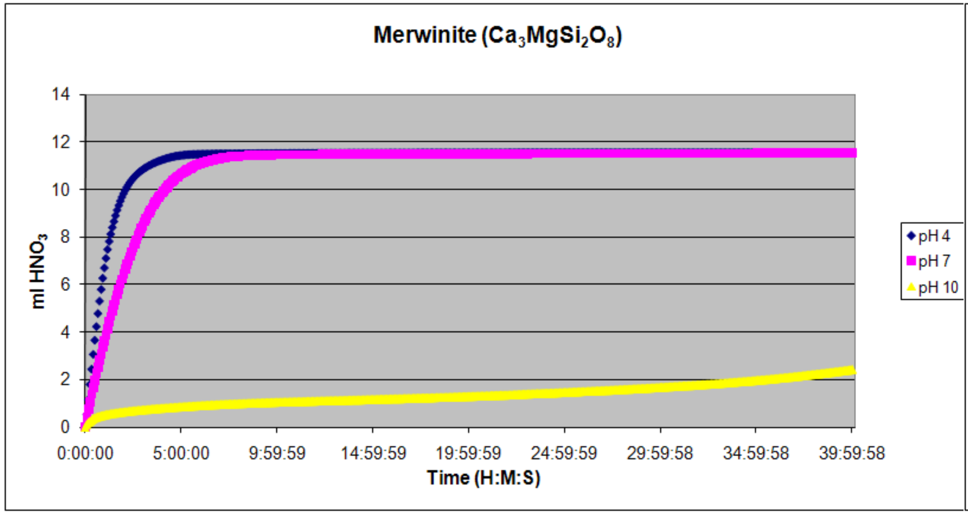
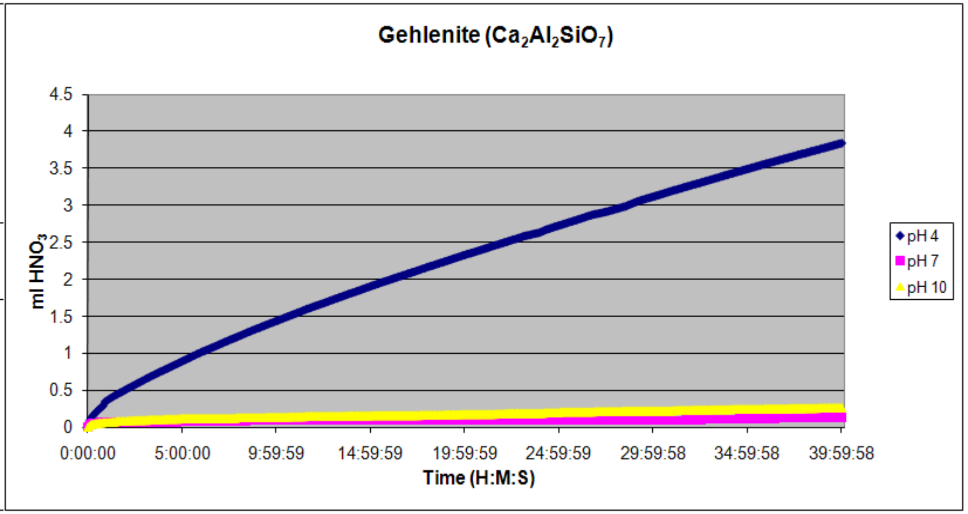
Synthetic slag minerals/titration

20-38 μm size fraction, 0.1 M HNO_3, 50 mg mineral / 100 ml H_2O

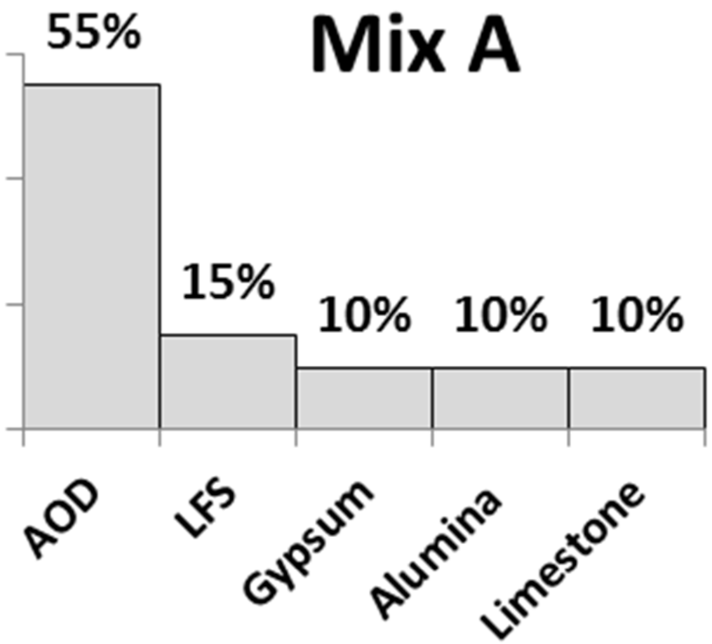


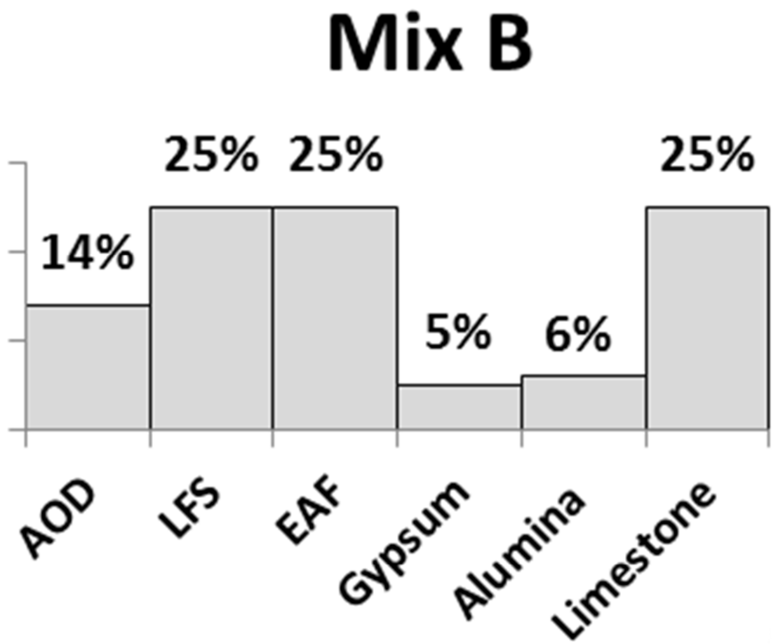




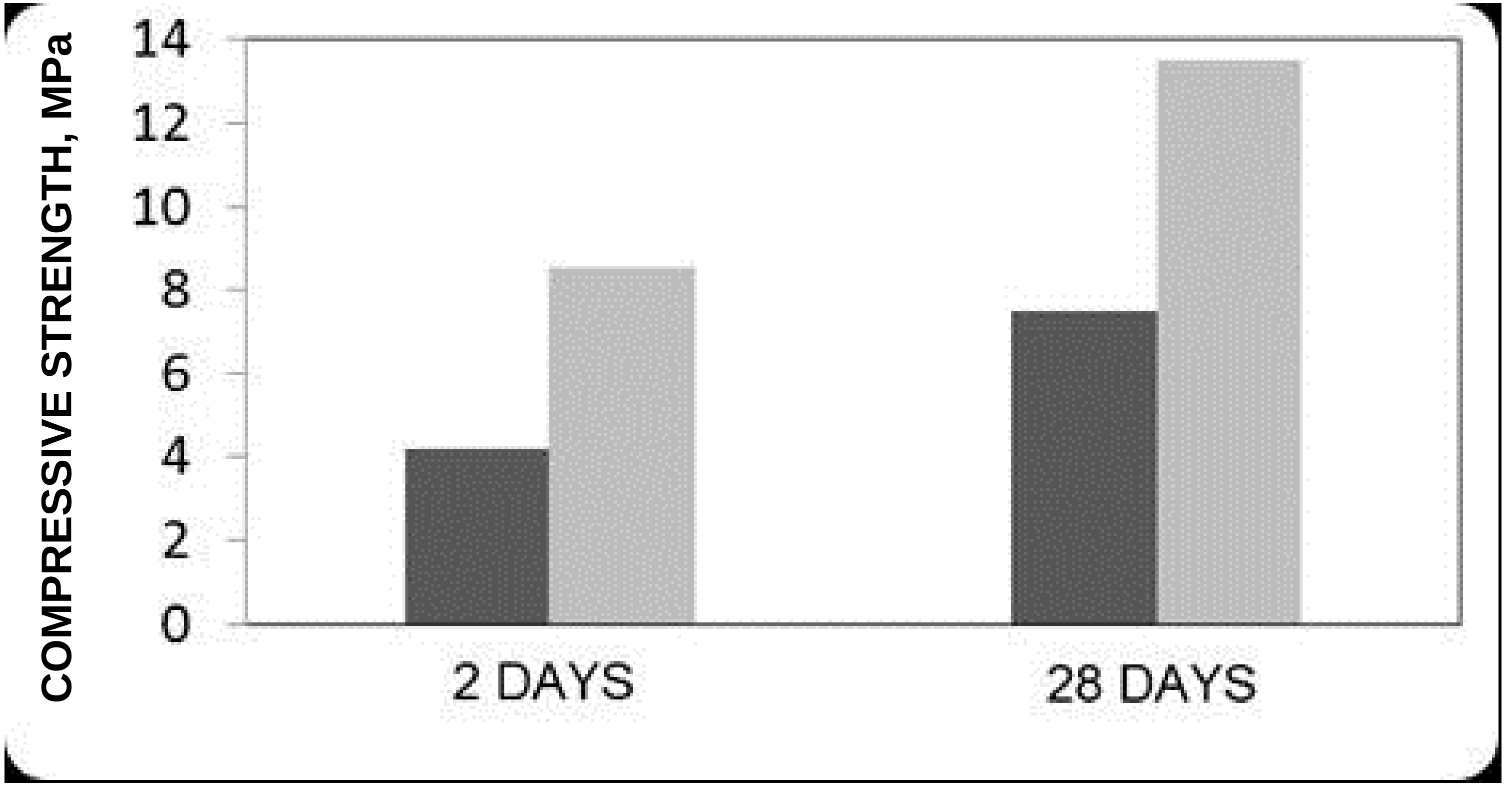


Use of steelmaking slag in production of a SAB-type cement

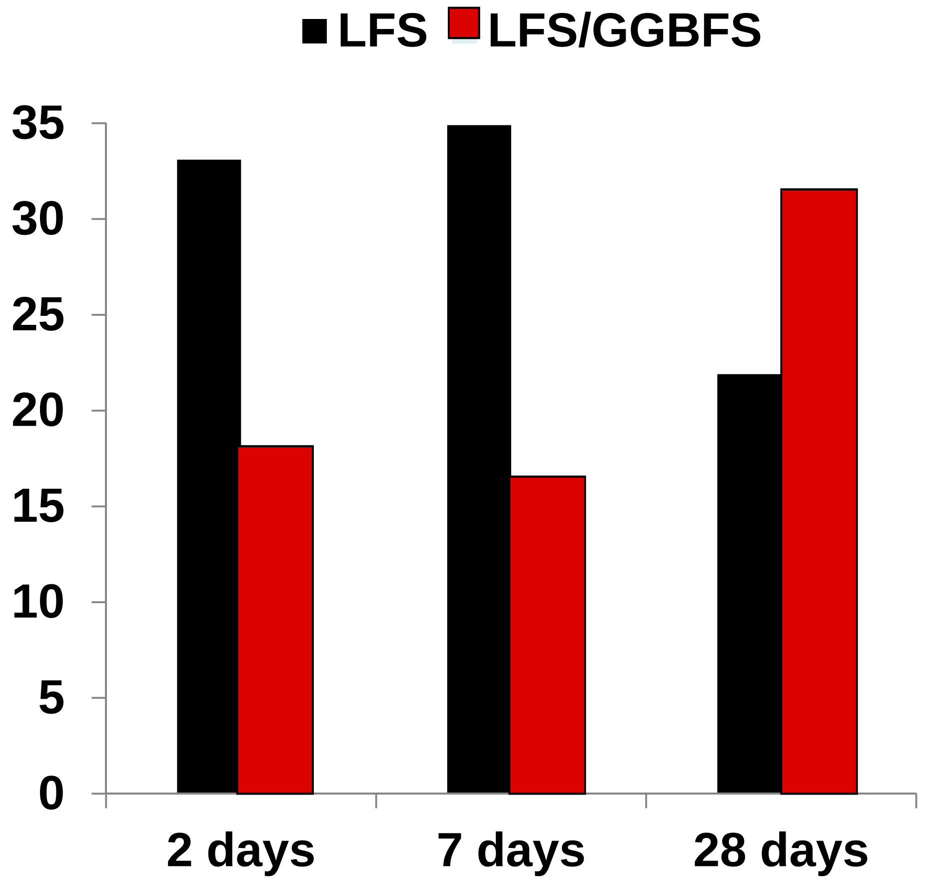




One mixture containing BOF slag and one with only ladle slag was also tested


COMPRESSIVE STRENGTH, MPa
14
12
10
8
6
4
2
0
2 DAYS
28 DAYS

Compressive strength for a ladle furnace slag and a mixture with GGBFS



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Thanks for listening!

Questions