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Istanbul Technical University
Metallurgical and Materials
Enginnering Dept.

Computational Studies on Steelmaking Processes by FactSage

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30.06.2016

Erdemir Group Companies and Products

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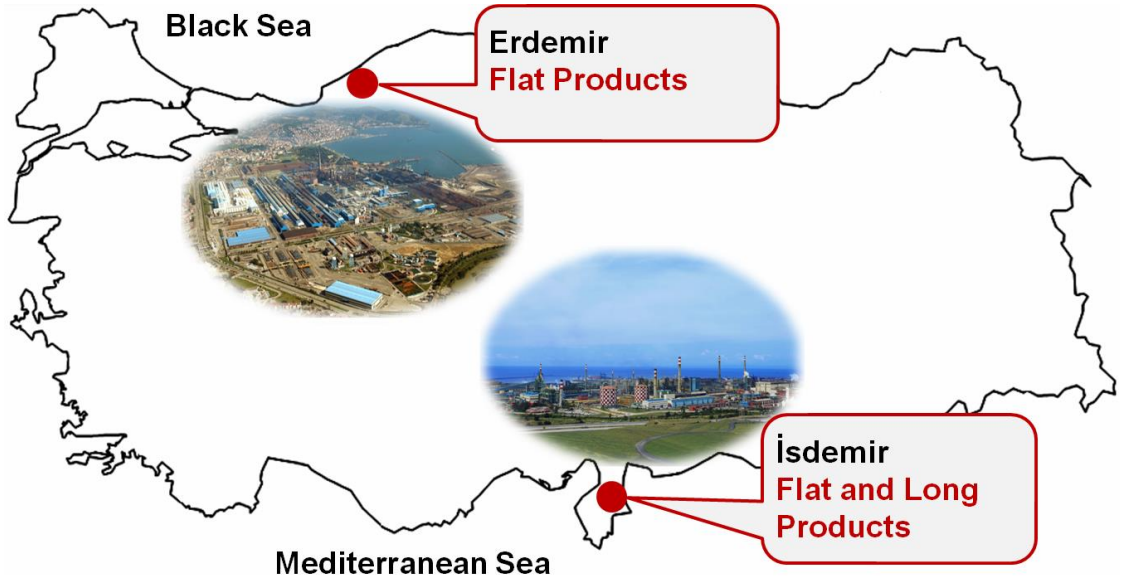
Erdemir Group Companies and Products

Steelmaking Plants



Other Group Companies

- ERMADEN (Mining)
- EROM (Electrical Steel Plant, Romania)
- ERSEM (Steel Service Center)
- ERDEMİR Engineering and Consulting Co.

Products

Flat Products

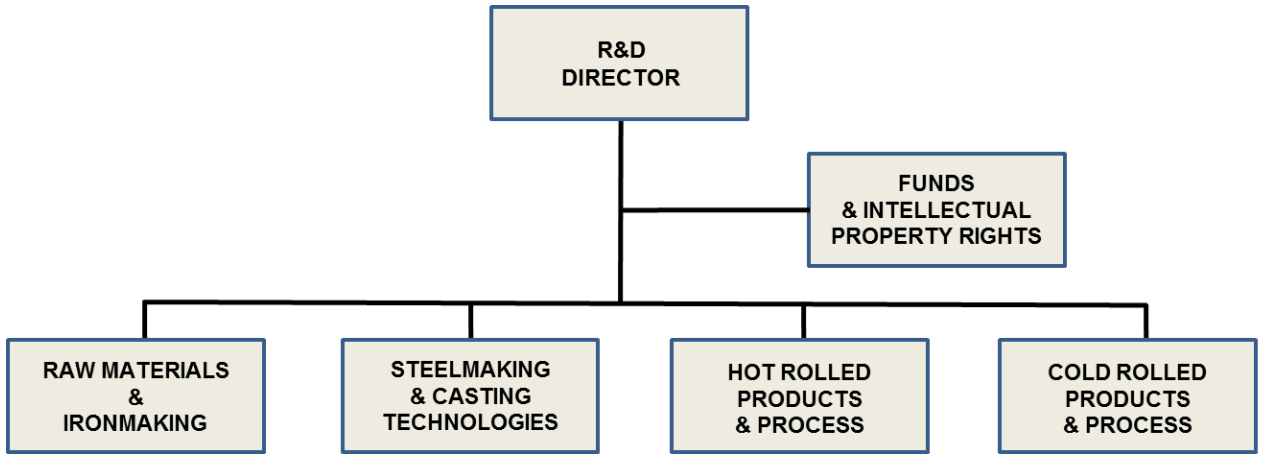
- Plate
- Hot rolled coil and sheet
- Cold rolled coil and sheet
- Tinplate
- Galvanised
- Electrical Steel

Long Products

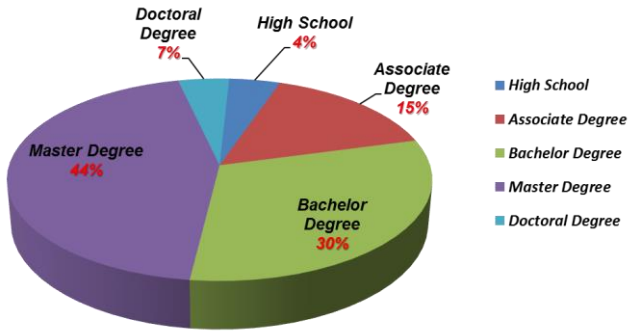
- Billets
- Wire Rod

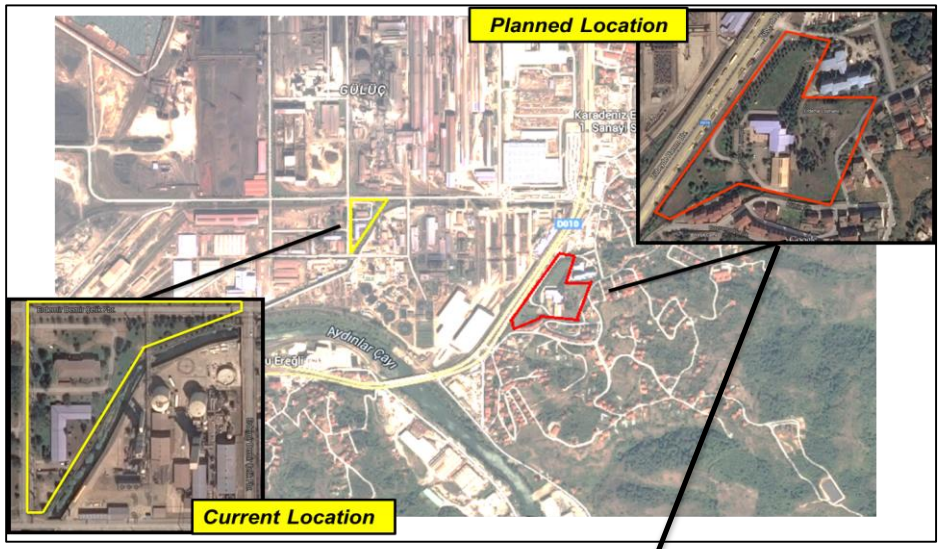
Erdemir R&D Center

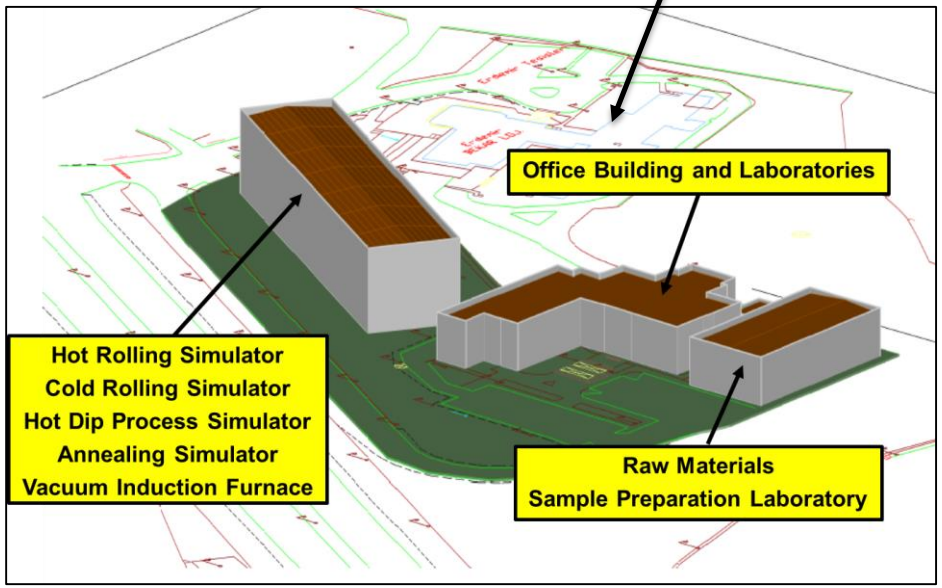
R&D Organization Chart



Educational Degree	No. of Employees
High School Graduate	**2**
Associate Degree	**7**
Bachelor Degree	**14**
Master Degree	**20**
Doctoral Degree	**3**







Outline

1. Case Study 1 – Usage of Colemanite Mineral for Boron Alloying Addition
2. Case Study 2 – Reducement of Ladle Nozzle Clogging in ULC Steel Grades
3. Case Study 3 – Usage of an Alternative Agent in Desulphurization Process
4. Case Study 4 – Estimation of Carry Over Slag Amount in Tapping Process

Case Study – 1 «Usage of Colemanite for Boron Alloying Addition»

Chemical Composition of Colemanite

Component	Content
B_2O_3	40.00 ±0.50 %
CaO	27.00 ±1.00 %
SiO_2	4.00-6.50%
SO_4	0.60% max.
As	35 ppm max.
Fe_2O_3	0.08% max.
Al_2O_3	0.40% max.
MgO	3.00% max.
SrO	1.50% max.
Na_2O	0.50% max.
L.O.I.	25.00% max.
Moisture	1.00% max.
Bulk Density	1.00 ton/m^3 max

ETiMADEN İŞLETMELERİ GENEL MÜDÜRLÜĞÜ

Location	Boron Mineral
Bigadiç Boron Works	Colemanite, Ulexite
Kırka Boron Works	Tincal
Emet Boron Works	Colemanite, Ulexite

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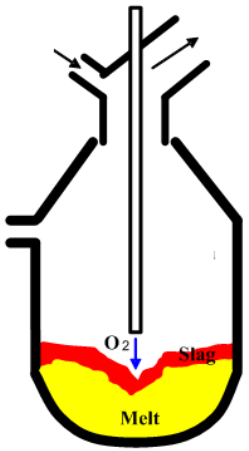
Case Study – 1 «Usage of Colemanite for Boron Alloying Addition»

Heat size: 120 ton steel

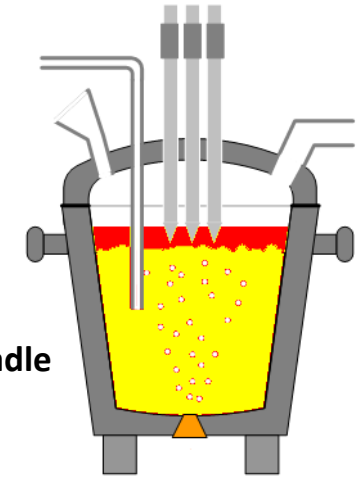
Aimed [B] content in steel grade specification: 20 – 40 ppm

Avarage FeB (18-20% B) Addition: 25-30 kg



BOF Process

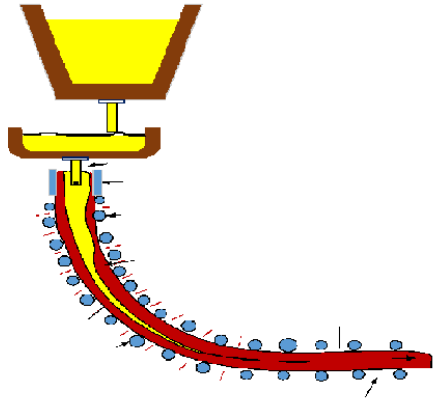
- Tapping additions to ladle (Lime, LDSF, etc.)
- Carry-over slag



LF Process

- Ladle additions (Ferro alloys, Aluminium, etc)

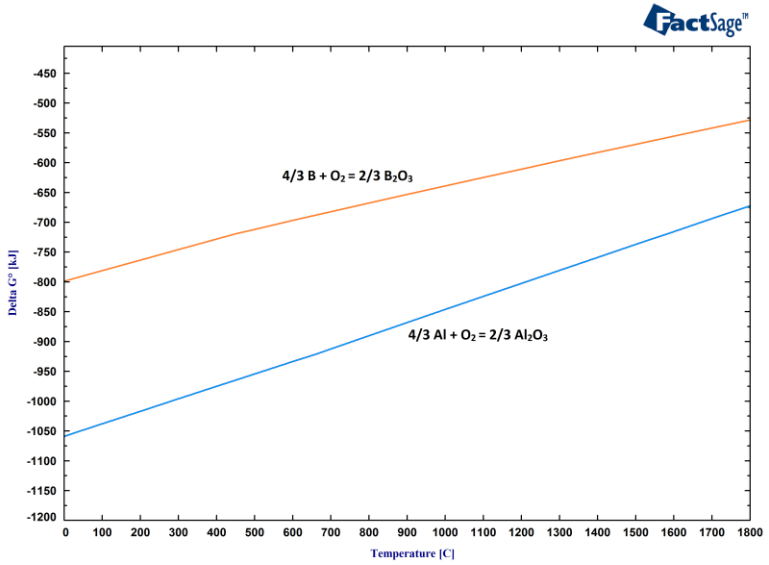
Colemanite addition



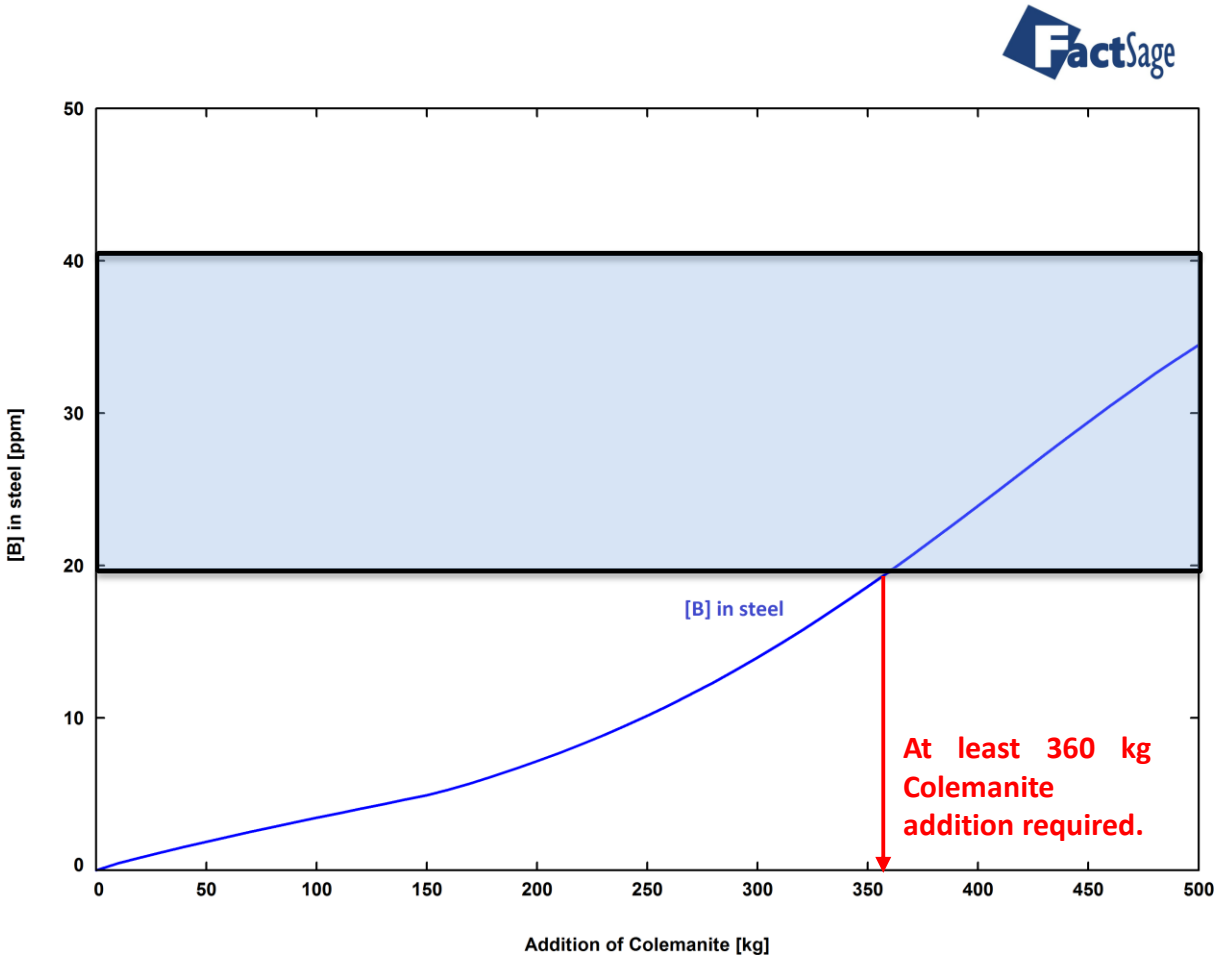
Continiuous Casting

Case Study – 1 «Usage of Colemanite for Boron Alloying Addition»

- **How much colemanite should be added into steel in order to have 20 – 40 ppm [B]?**

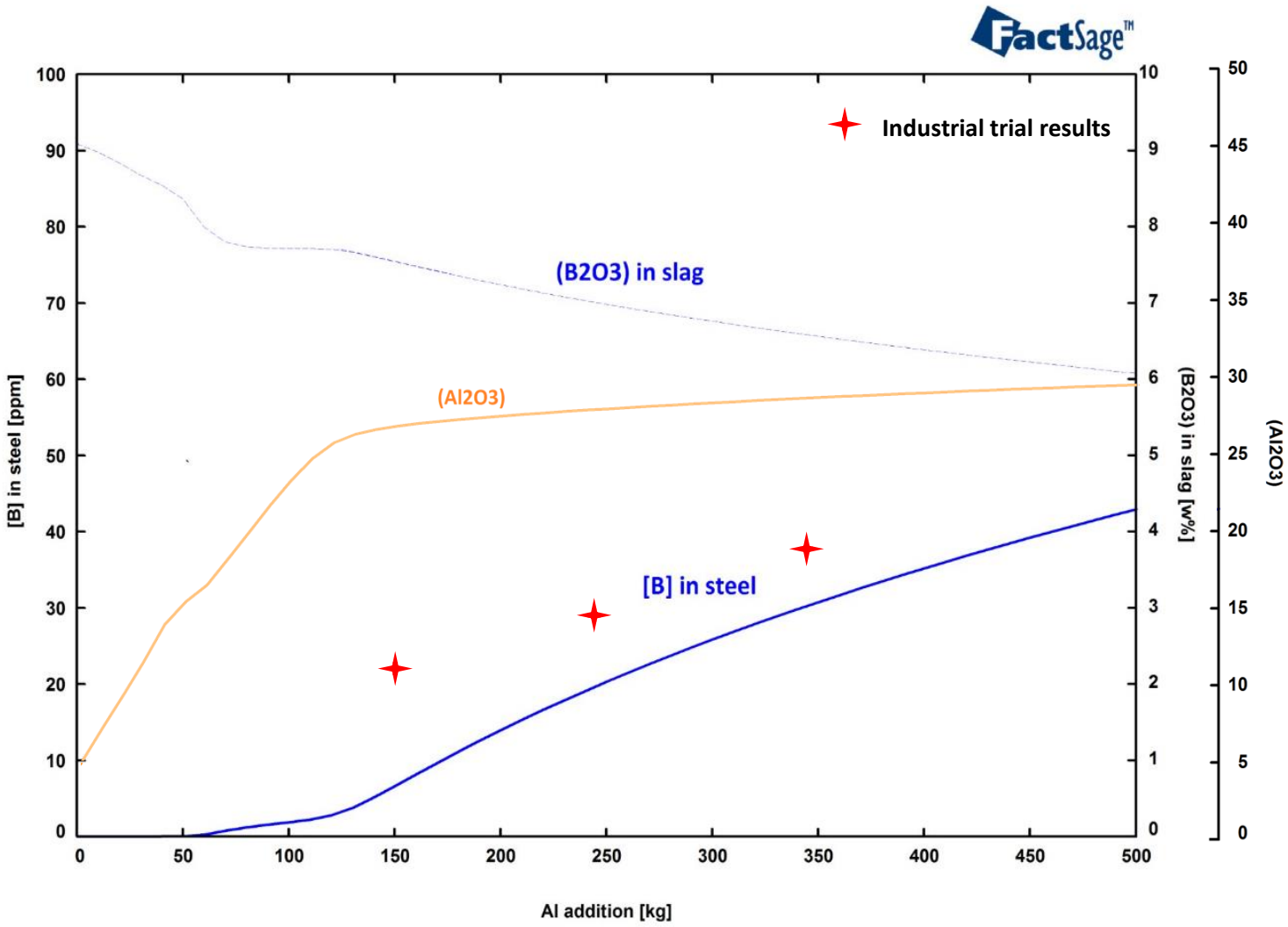


- **Colemanite (B_2O_3 compound) should be reduced from slag with using Al in order to have desired [B] in liquid steel.**



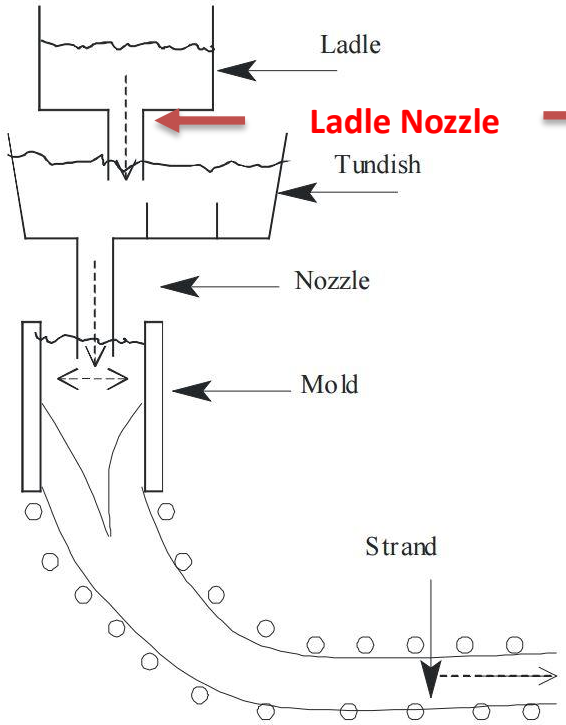
Case Study – 1 «Usage of Colemanite for Boron Alloying Addition»

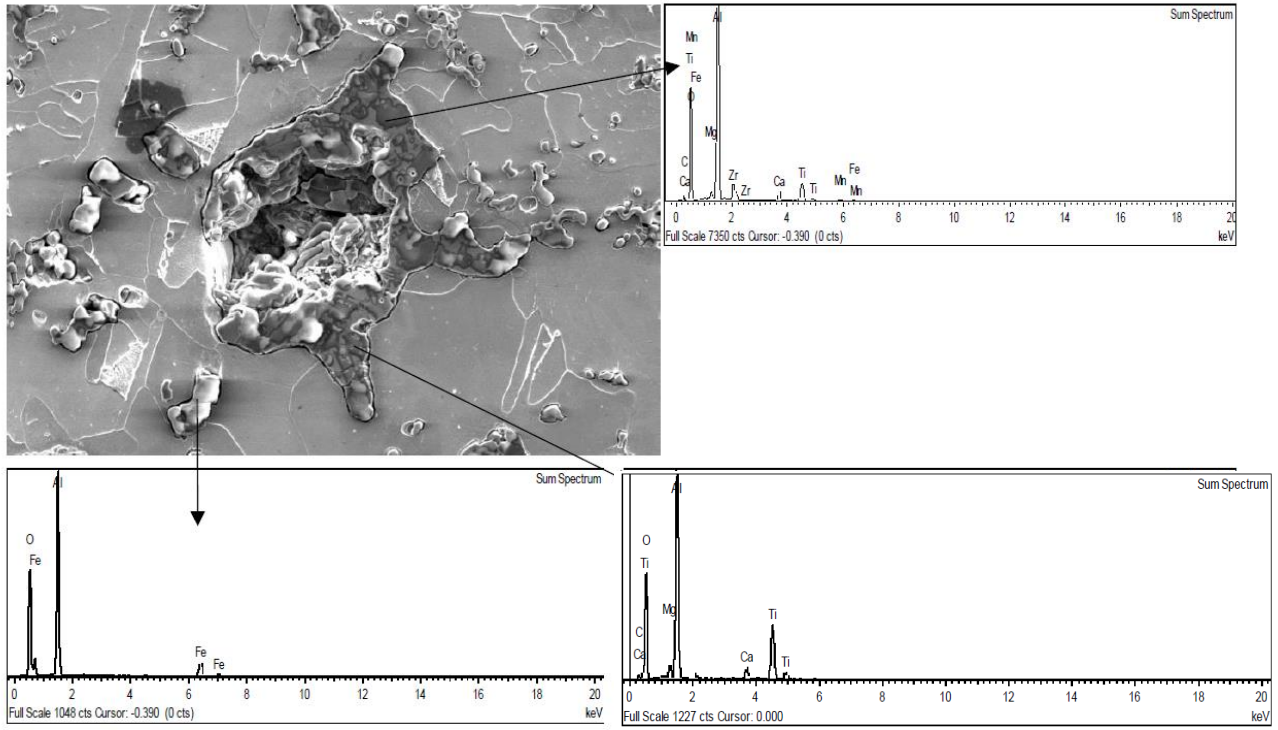
- Industrial trials were performed with 150, 250 and 350 kg Al after 150 kg colemanite addition.
- 250 kg Al addition was found to be enough to have 30 ppm [B] in liquid steel.
- The Al addition produces (Al_2O_3) formations which may results negative effects on steel cleanliness.



Case Study – 2 «Reducing Ladle Nozzle Clogging in ULC Steel Grades»

Problem: Reducing casting speed and/or returning heats by the reason of clogging in ladle inner nozzle.



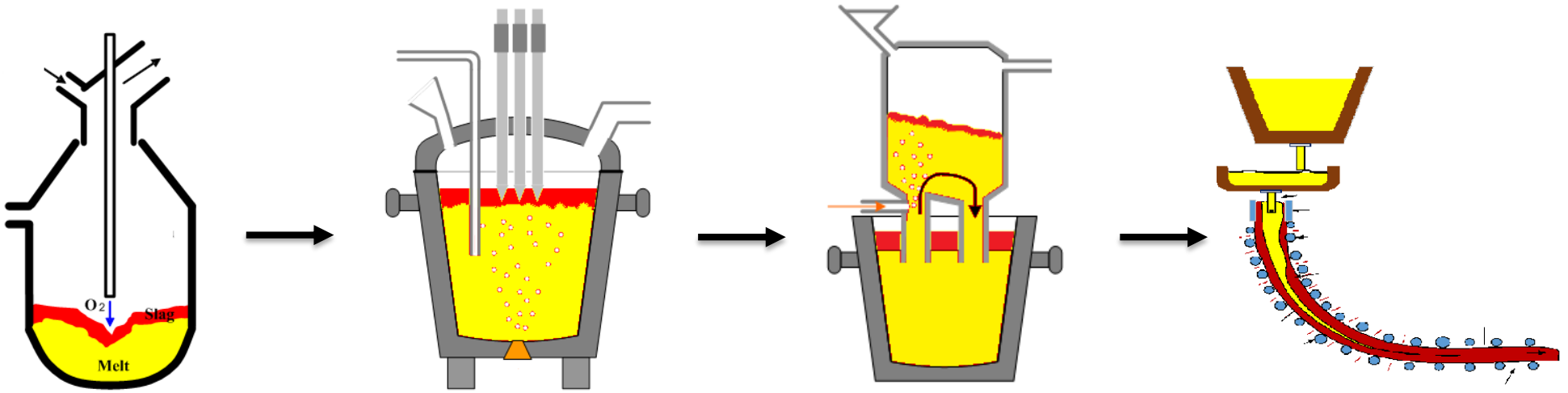


Clogged Ladle Nozzle inner wall SEM/EDS Analysis:
Major inclusions are Al_2O_3 and TiOx. Al_2O_3

Case Study – 2 «Reducing Ladle Nozzle Clogging in ULC Steel Grades»

Chemical Composition of ULC Steel Grade

C	Mn	Si	S	P	N	Al	Ti
30 max.	.10-.20	.030	.015	.015	.005	.020-.050	.065-.075



BOF Process → **LF Process** → **RH-KTB** → **Continiuous Casting**

- De-carburization
- De-oxidation with Aluminium
- Titanium addition

Case Study – 2 «Reducing Ladle Nozzle Clogging in ULC Steel Grades»

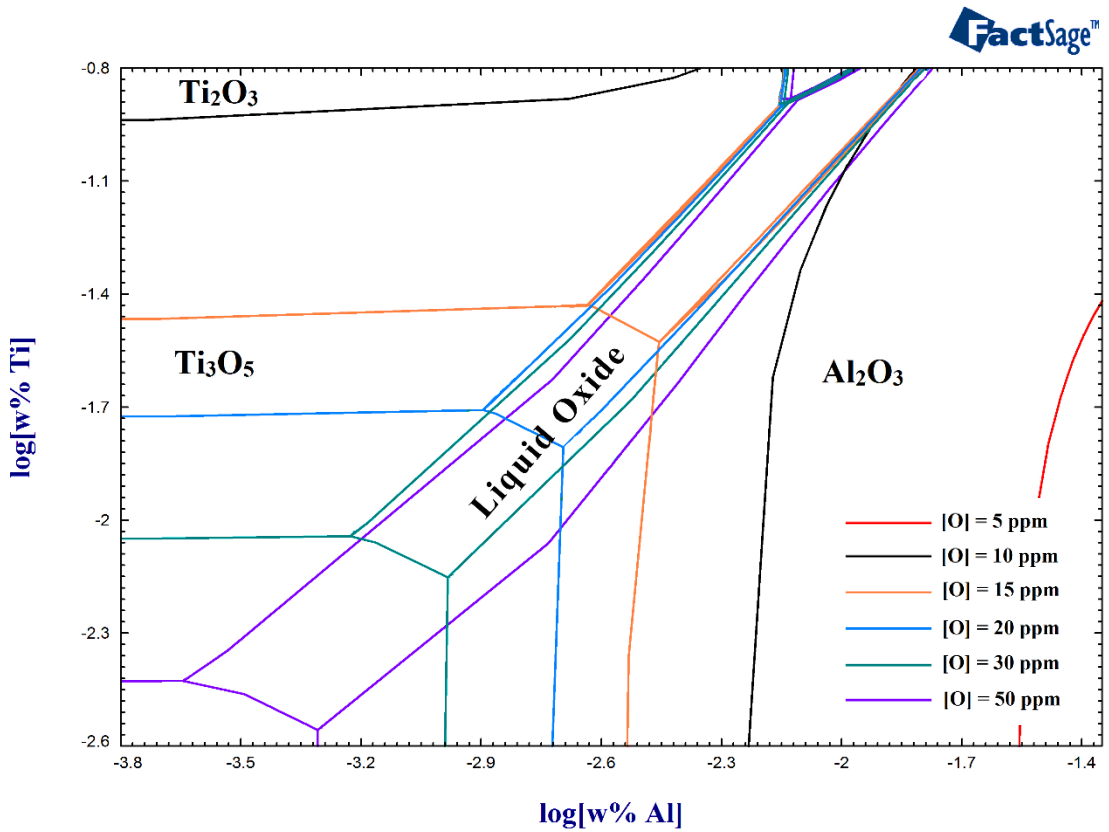


Fig.: Liquid oxide window depending on Ti-Al-O in steel at 1600°C.

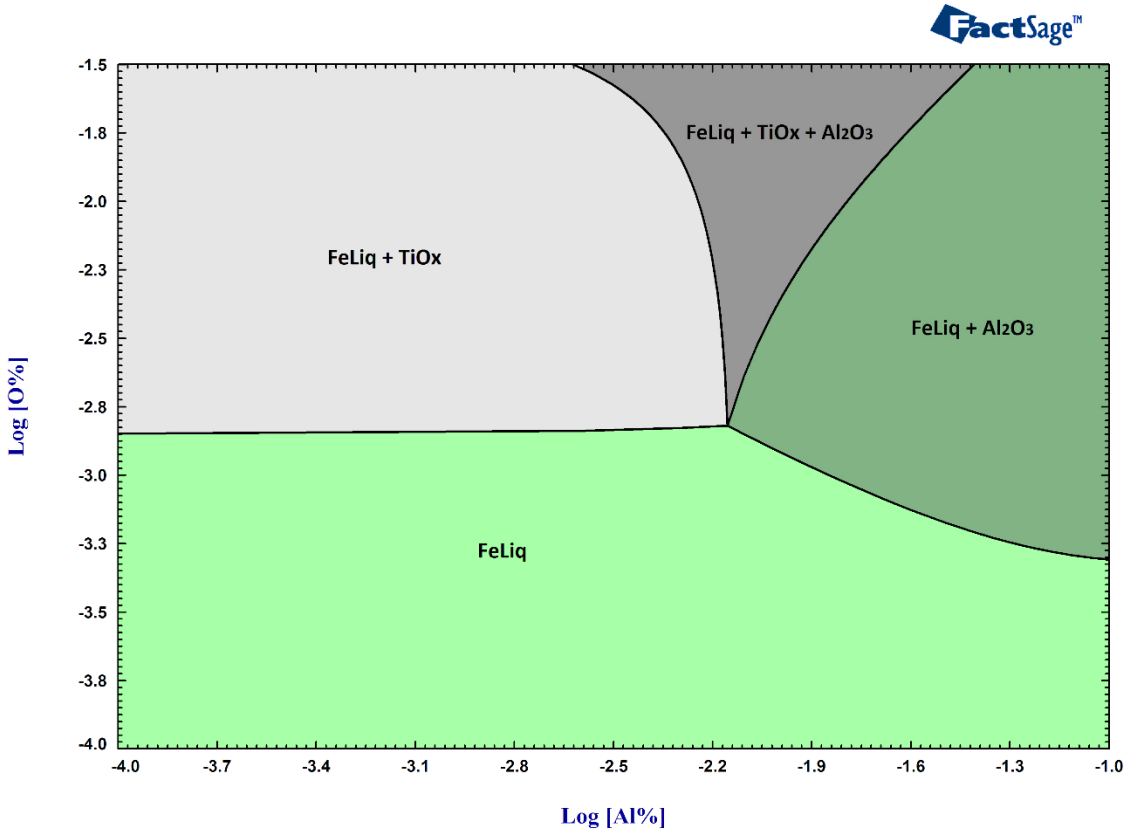
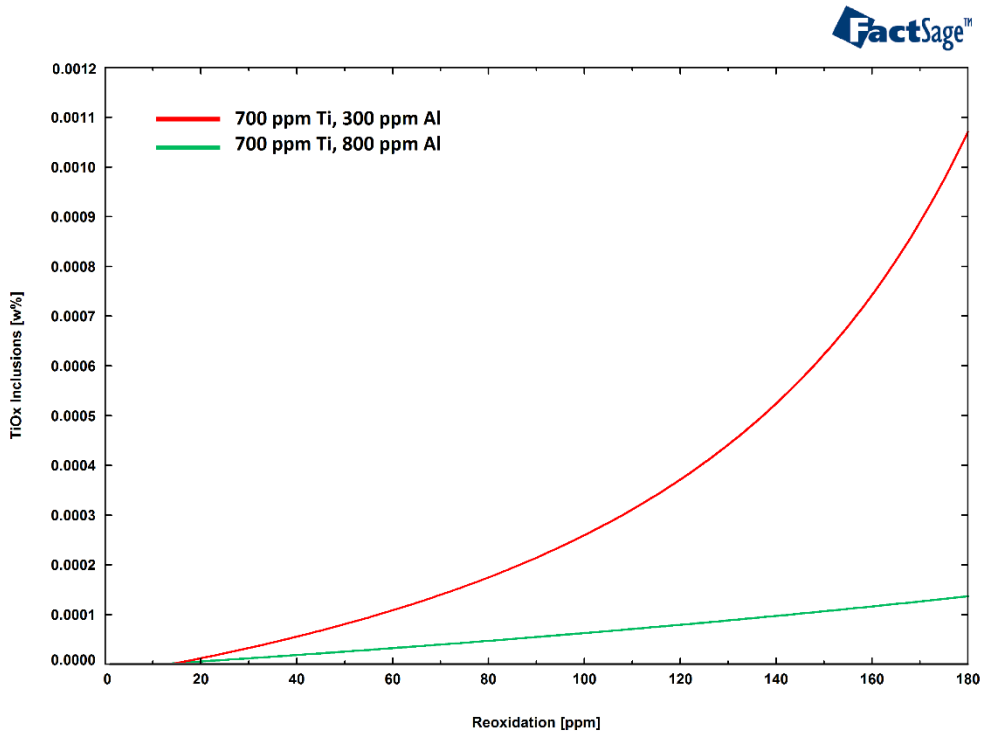
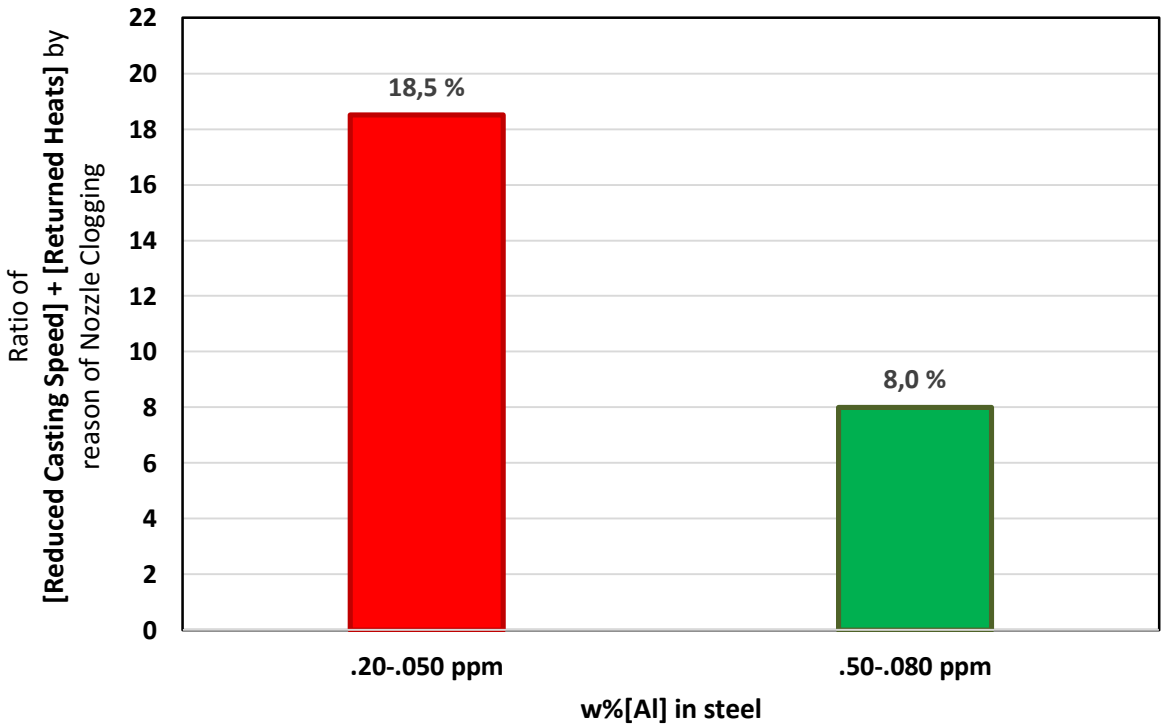


Fig.: Al-O stability diagram of 700 ppm Ti bearing steel at 1600°C.

Trials were planned with increasing w%[Al] content [.020-.050] to [.050-.080] in order to see clogging behaviour for a number of 50 ULC heats period.

Case Study – 2 «Reducing Ladle Nozzle Clogging in ULC Steel Grades»

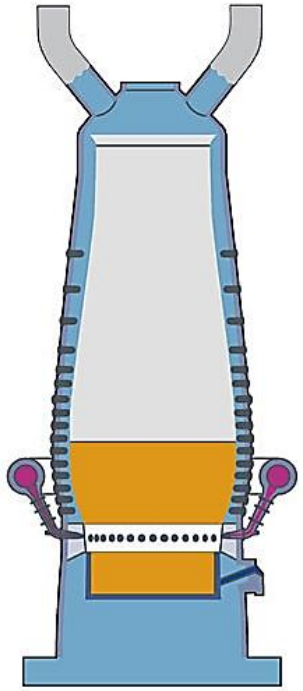




Reducing casting speed and/or returning heats ratio by the reason of clogging in ladle inner nozzle is decreased from 18,5% to 8,0% by increasing w%[Al] in steel from [.020-050] to [.050-080].

Case Study – 3 «Usage of an Alternative Agent in Desulphurization Process»

Desulphurization Process



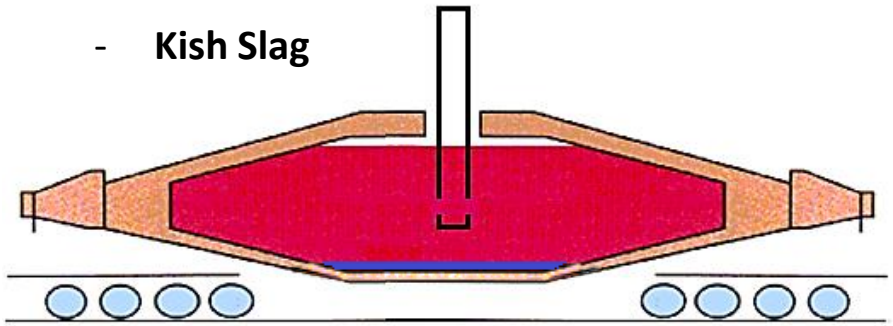
Blast Furnace (BF)

- Hot Metal
- BF slag

Trisodium Hexafluoroaluminate (Na_3AlF_6)

- CaO mix (CaO + CaF_2)
- Granulated Mg

- Kish Slag



Desulphurization in Torpedo

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Case Study – 3 «Usage of an Alternative Agent in Desulphurization Process»

Trisodium Hexafluoroaluminate (Na_3AlF_6): Replacement of CaF_2 for steelmaking as a slag conditioner.

Substance Name	Concentration [w%]
Trisodium Hexafluoroaluminate	75.00
Aluminium-Fluoride	< 15.00
Aluminium Oxide	10.00 – 25.00

Hot Metal Composition [w%]			
Carbon	4.35	Phosphorus	0.09
Manganese	0.25	Sulphur	0.11
Silicon	0.35	Titanium	0.02

FactSage – Reactans / Equilib [1390 °C]:

100 t Hot Metal + 0.800 t (BF + Kish Slag) + <0.85A> t CaO + <0.15A> t CaF_2 or Na_3AlF_6 + <0.10A> t Mg

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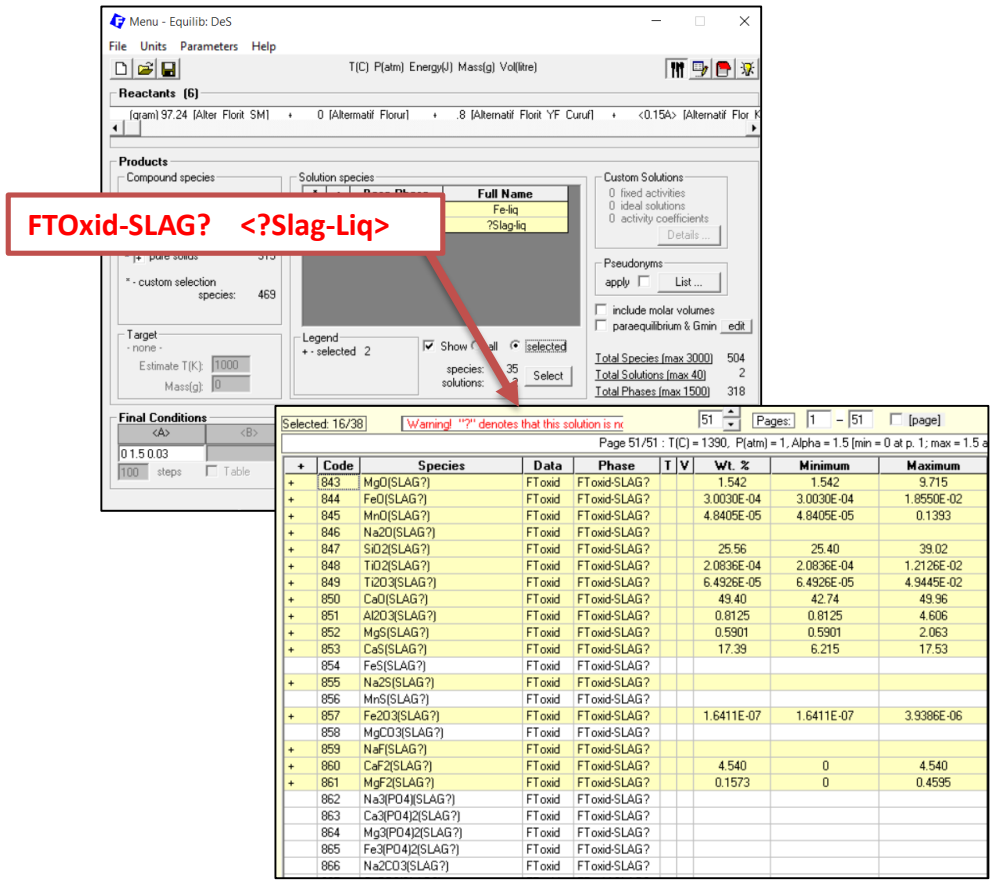
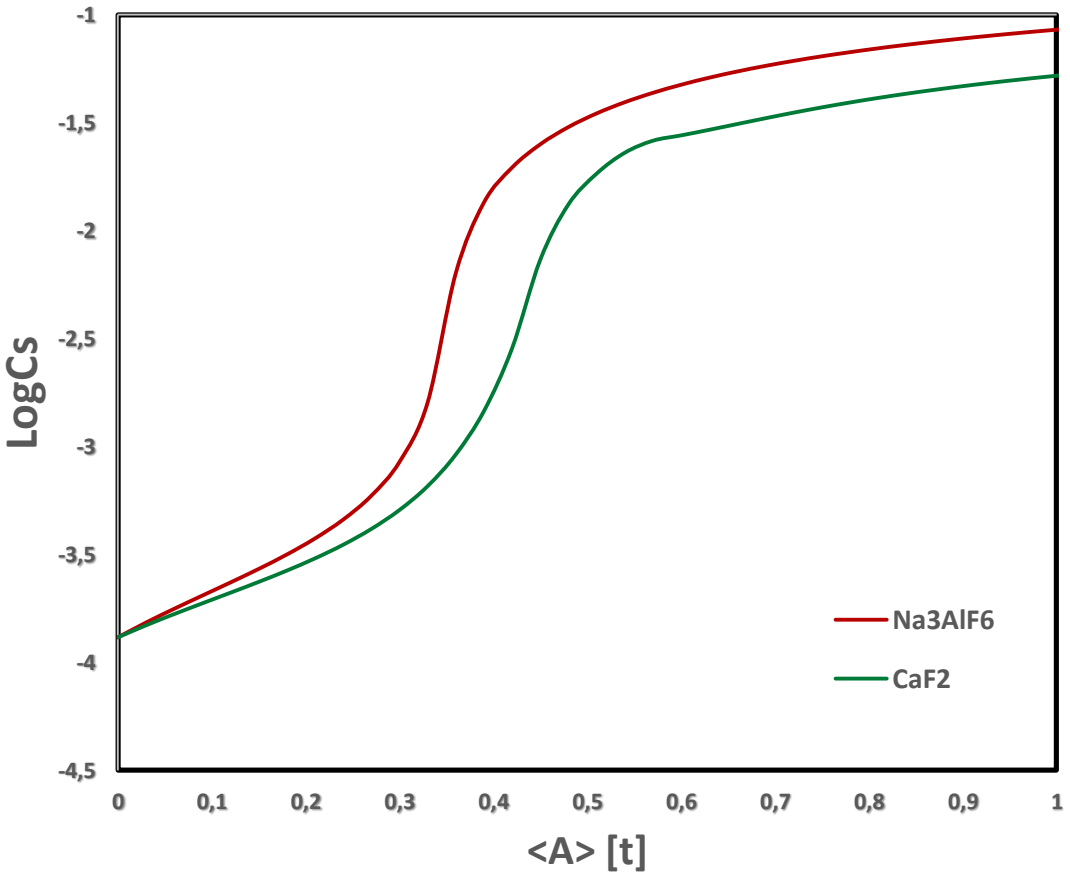
Case Study – 3 «Usage of an Alternative Agent in Desulphurization Process»



+	Code	Species	Data	Phase	T	V	Wt. %	Minimum	Maximum
+	843	MgO(SLAG?)	FToxid	FToxid-SLAG?			1.542	1.542	9.715
+	844	FeO(SLAG?)	FToxid	FToxid-SLAG?			3.0030E-04	3.0030E-04	1.8550E-02
+	845	MnO(SLAG?)	FToxid	FToxid-SLAG?			4.8405E-05	4.8405E-05	0.1393
+	846	Na2O(SLAG?)	FToxid	FToxid-SLAG?					
+	847	SiO2(SLAG?)	FToxid	FToxid-SLAG?			25.56	25.40	39.02
+	848	TiO2(SLAG?)	FToxid	FToxid-SLAG?			2.0836E-04	2.0836E-04	1.2126E-02
+	849	Ti2O3(SLAG?)	FToxid	FToxid-SLAG?			6.4926E-05	6.4926E-05	4.9445E-02
+	850	CaO(SLAG?)	FToxid	FToxid-SLAG?			49.40	42.74	49.96
+	851	Al2O3(SLAG?)	FToxid	FToxid-SLAG?			0.8125	0.8125	4.606
+	852	MgS(SLAG?)	FToxid	FToxid-SLAG?			0.5901	0.5901	2.063
+	853	CaS(SLAG?)	FToxid	FToxid-SLAG?			17.39	6.215	17.53
	854	FeS(SLAG?)	FToxid	FToxid-SLAG?					
+	855	Na2S(SLAG?)	FToxid	FToxid-SLAG?					
	856	MnS(SLAG?)	FToxid	FToxid-SLAG?					
+	857	Fe2O3(SLAG?)	FToxid	FToxid-SLAG?			1.6411E-07	1.6411E-07	3.9386E-06
	858	MgCO3(SLAG?)	FToxid	FToxid-SLAG?					
+	859	NaF(SLAG?)	FToxid	FToxid-SLAG?					
+	860	CaF2(SLAG?)	FToxid	FToxid-SLAG?			4.540	0	4.540
+	861	MgF2(SLAG?)	FToxid	FToxid-SLAG?			0.1573	0	0.4595
	862	Na3(PO4)(SLAG?)	FToxid	FToxid-SLAG?					
	863	Ca3(PO4)2(SLAG?)	FToxid	FToxid-SLAG?					
	864	Mg3(PO4)2(SLAG?)	FToxid	FToxid-SLAG?					
	865	Fe3(PO4)2(SLAG?)	FToxid	FToxid-SLAG?					
	866	Na2CO3(SLAG?)	FToxid	FToxid-SLAG?					

Sulphide Capacity (LogCs) of DeS Slag



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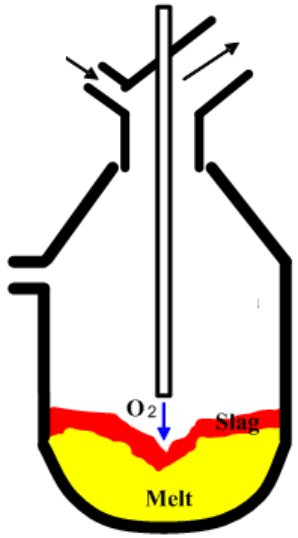
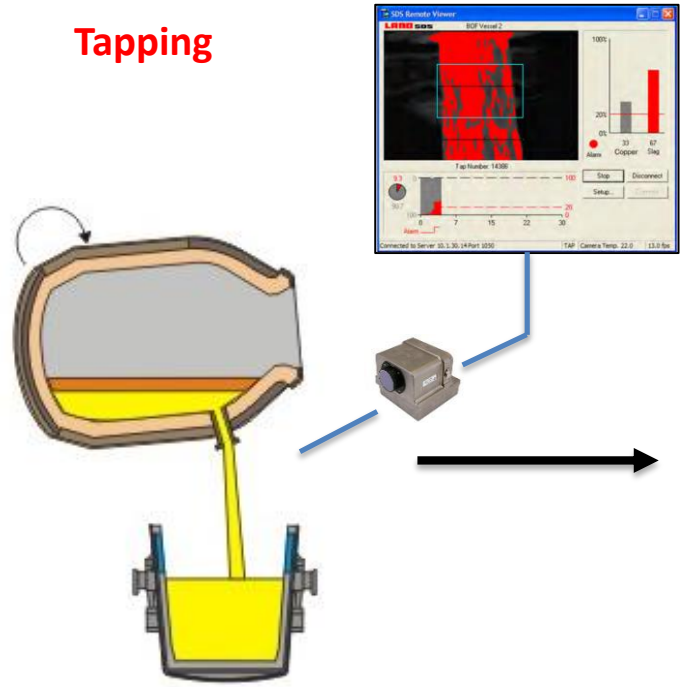
Case Study – 4 «Estimation of Carry Over Slag Amount in Tapping Process»

BOF Process

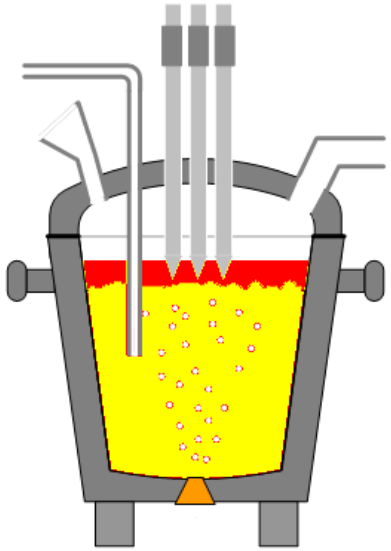


Tapping

Slag Detection System



LF Process



Steel Sample
[BOF END]
[Al]: 0%

- **Laddle Additions**
(Deoxidizers, Fluxes, Alloys, etc.)
- **Carry Over Slag**

Steel Sample
[LF INITIAL]
[Al]: ?%

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Case Study – 4 «Estimation of Carry Over Slag Amount in Tapping Process»

«Equilib» Inputs Data

- **BOF End Process Liquid Steel** — **120 t**
  - [C] : 0,030%
  - [Mn] : 0,090%
  - [P] : 0,012%
  - [S] : 0,012%...
  - **[O] : 700-900 ppm**
  - **[Al] : 0,000%**

- **Tapping Additions**
  - FeMn (Alloying) — 160 kg
  - Coke (Pre-deoxiding) — 20 kg
  - **Al (Deoxidizer) — 160 kg**
  - LDSF (Slag modifing) — 180 kg

- **Carry Over Slag** — **<A> Kg**
  - (FeO) : 20,0%
  - (SiO2) : 15,1%
  - (MnO) : 3,10%
  - (CaO) : 55,1%...

«Equilib» Results Data

LF STEEL CHEMICAL COMPOSITIONS [%]

Element	Min.	Max.	BOF END	LF-1	LF-2			CCM
C			0,0305	0,0345	0,0345			0,0348
Mn			0,0862	0,1247	0,1810			0,1829
P			0,0125	0,0129	0,0135			0,0135
S			0,0121	0,0120	0,0102			0,0110
Si			0,0027	0,0031	0,0043			0,0056
Al			0,0000	0,0109	0,0586			0,0344
Cu			0,0257	0,0232	0,0236			0,0241
Cr			0,0126	0,0103	0,0115			0,0141
Ni			0,0339	0,0372	0,0370			0,0372
V			0,0013	0,0014	0,0019			0,0021
Nb			0,0034	0,0005	0,0006			0,0007
Ca			0,0001	0,0002	0,0000			0,0000
Ti			0,0000	0,0006	0,0008			0,0008
Zr			0,0000	0,0002	0,0004			0,0004
B			0,0002	0,0000	0,0000			0,0000
Nppm			0,0023	0,0026	0,0028			0,0032
Oppm			0,0782					
NOTES:								

ERD01 GRADE STEEL

LF Process Heat Report

Steel Sample Chemical Compositions

- **Ladle Furnace Initial Steel Sample**
  - [C] :
  - [Mn] :
  - [P] :
  - [S] :
  - **[Al] : x %**

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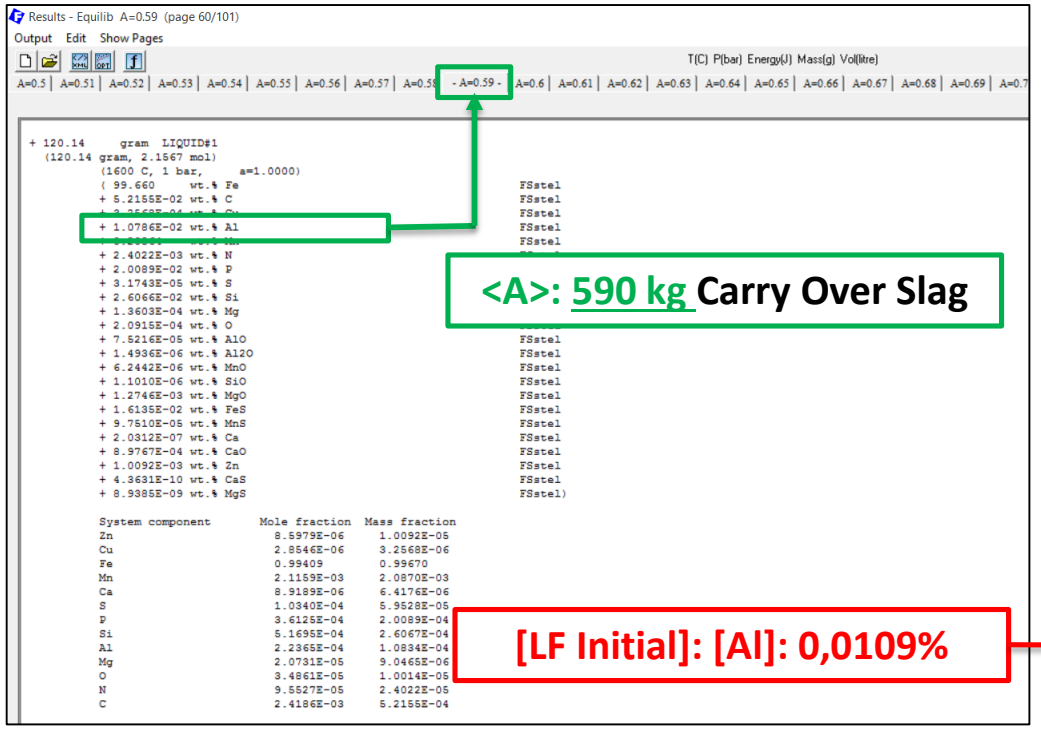
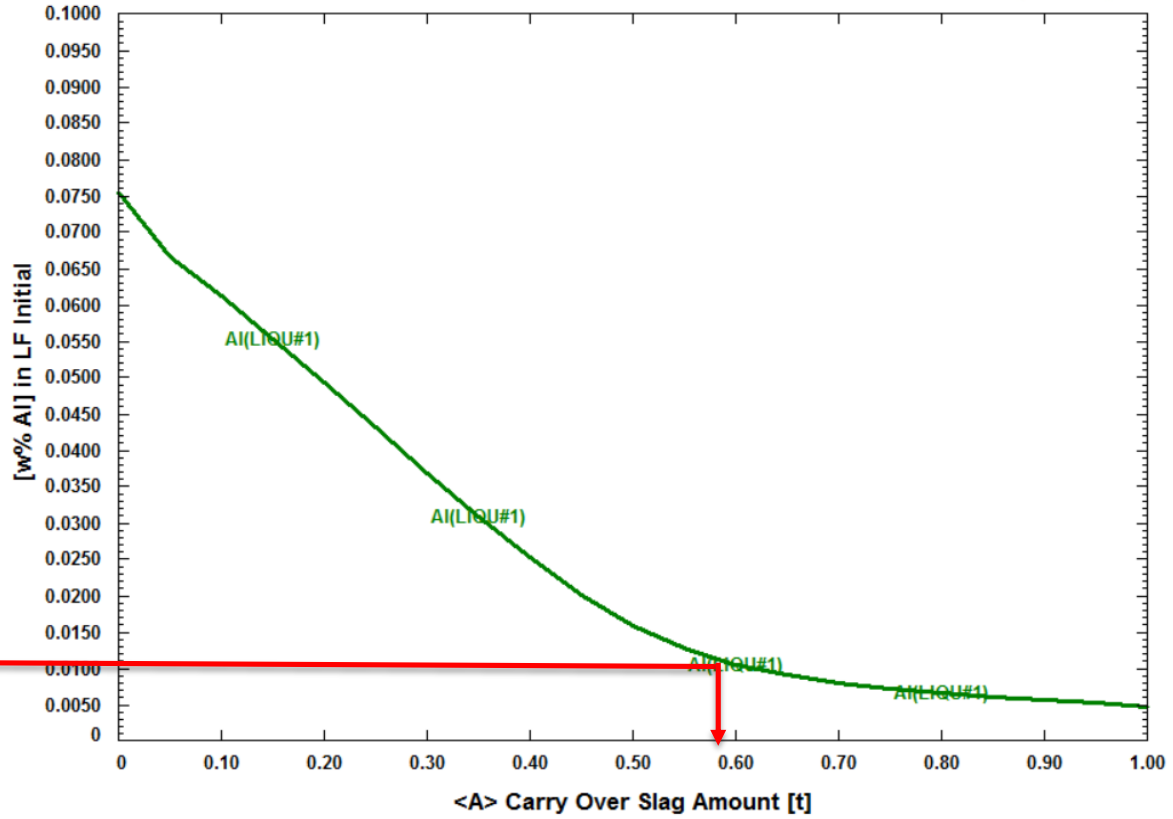
Case Study – 4 «Estimation of Carry Over Slag Amount in Tapping Process»



<A>: 590 kg Carry Over Slag

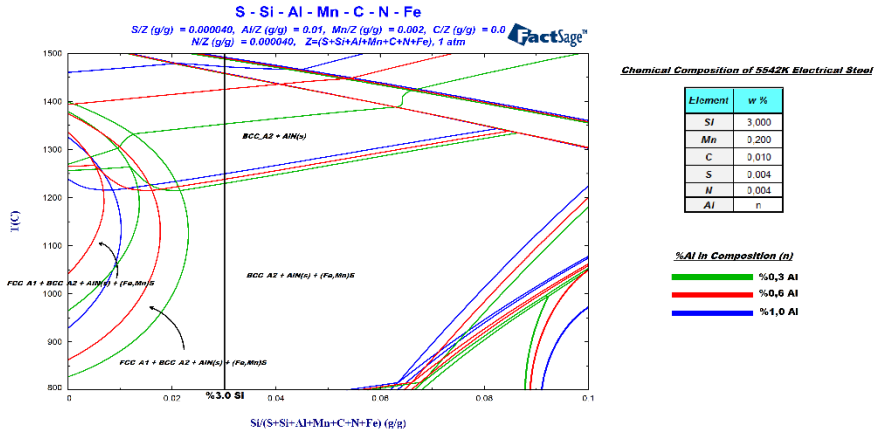
[LF Initial]: [Al]: 0,0109%



Validation trials will be performed with Heraeus «Slag Probe – Delta Dist L» slag thickness and freeboard measurement system.

Other Activities with FactSage

Fe-Si Phase Diagram with Different [Al] Contents



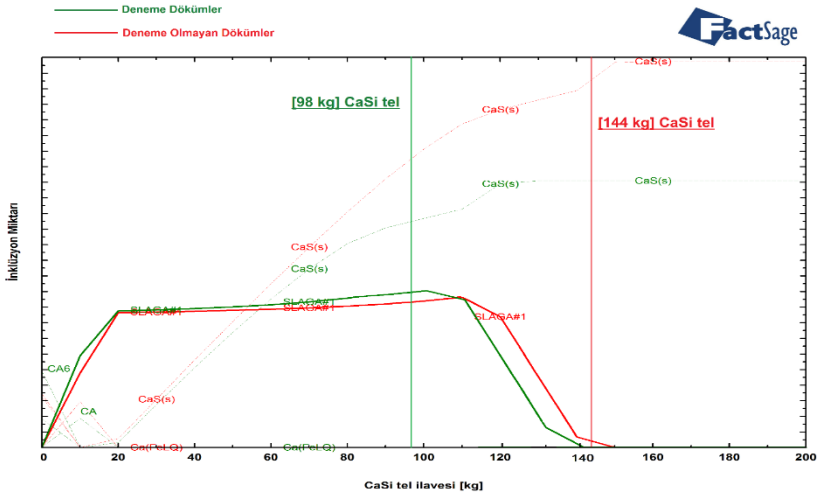
Chemical Composition of 5542K Electrical Steel

Element	w %
Si	3,000
Mn	0,200
C	0,010
S	0,004
N	0,004
Al	n

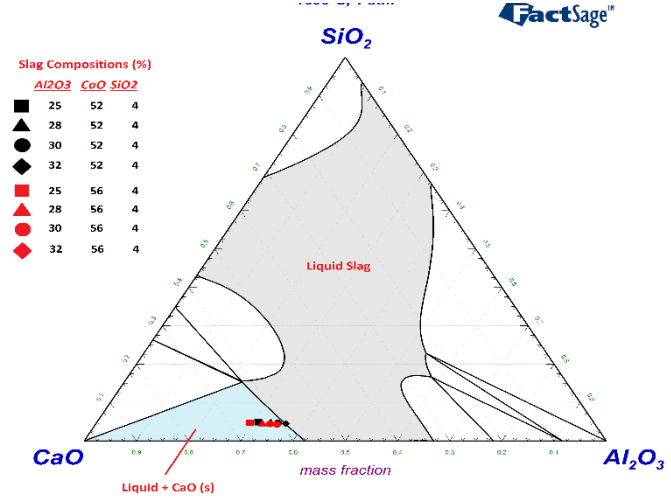
%Al in Composition (n)

- %0,3 Al
- %0,6 Al
- %1,0 Al

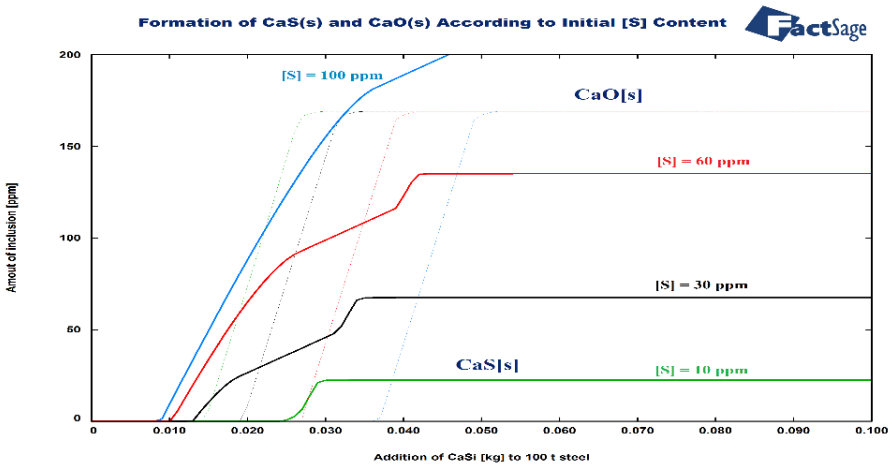
Formation of Inclusions During Calcium Treatment



Al_2O_3 – SiO_2 – CaO Ternary System for BOF Slag



Formation of CaS and CaO According to Initial [S] Content



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Thank You For Your Attention.

Ereğli Iron and Steel Works, Co. (Erdemir)
R&D Center

Istanbul Technical University
Metallurgical and Materials Enginnering Dept.