Basic Oxygen Furnace

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What is the BOF ?

- Basic Oxygen Furnace (BOF) is a steel making furnace, in which molten pig iron and steel scrap convert into steel due to oxidizing action of oxygen blown into the melt under a basic slag.
- Primary steelmaking
- Known as Linz-Donawitz-Verfahren steelmaking

History

- In 1856, Henry Bessemer patented a steelmaking process involving oxygen blowing for decarburizing molten iron.
- For nearly a hundred years commercial quantities of oxygen were not available at all or were too expensive, and the invention remained unused

History

- The process was developed in 1948 by Robert Durrer in Switzerland.
- by commercialized in 1952-1953 by Austrian VOEST and ÖAMG is an international steel based technology and capital goods group based in Linz.

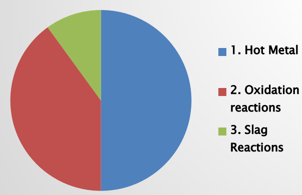
Basic Functions of BOF

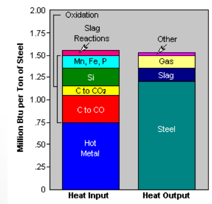
- To decarburize and remove phosphorus from the hot metal.
- To optimize the steel temperature for casting with no further heat treatments.

What about energy?

Required energy: 1.5 million Btu per ton of steel

BTU:1055J



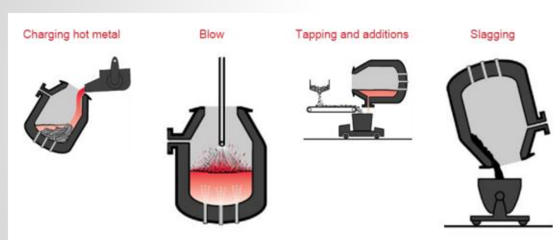


Adapted from: "The Making, Shaping, and Treating of Steel" 10th Edition, Association of Iron and Steel Engineers, 1985, p. 602.

How does BOF work?

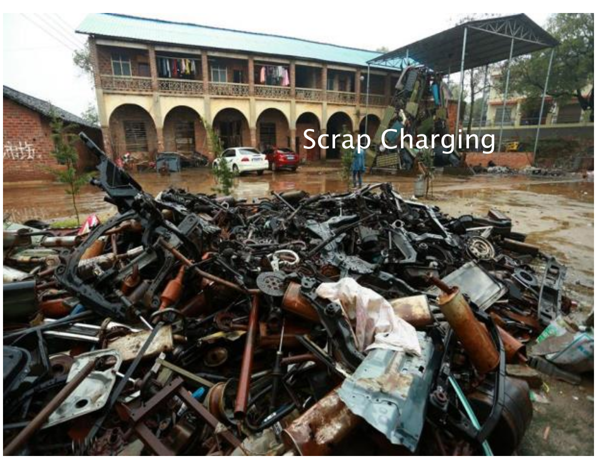
- Charging hot metal
- Blow
- Tapping and additions
- Slagging

How does BOF work?

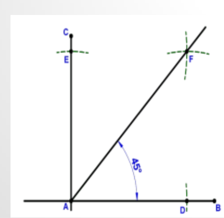


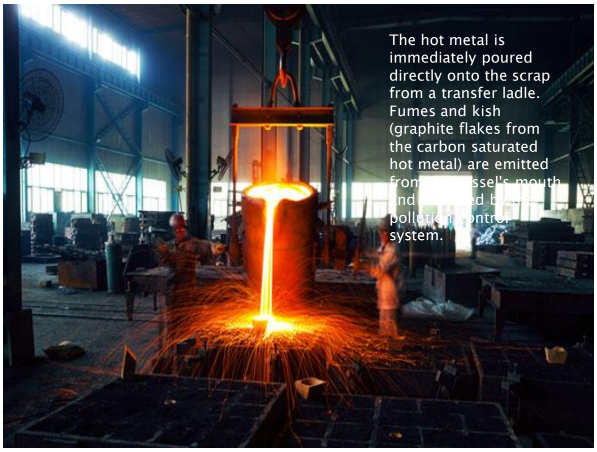
1-Charging Hot Metal

Hot metal is melted pig iron in a furnace.

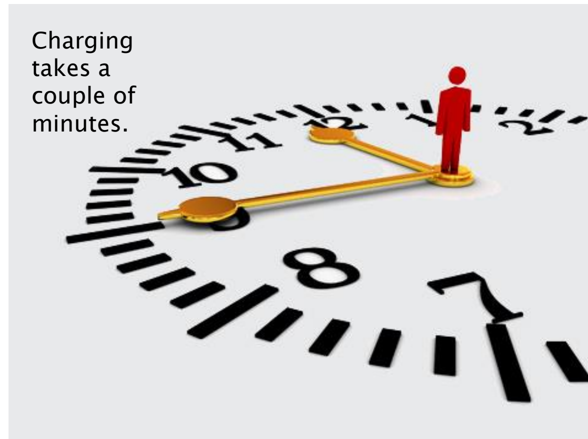


"heating" begins when the BOF vessel is tilted about 45 degrees towards the charging aisle and scrap charge (about 25 to 30% of the heat weight) is dumped from a charging box into the mouth of the cylindrical BOF.





The hot metal is immediately poured directly onto the scrap from a transfer ladle. Fumes and kish (graphite flakes from the carbon saturated hot metal) are emitted from [illegible] ssel's mouth and [illegible] d b[illegible] polluti[illegible] ontrol system.

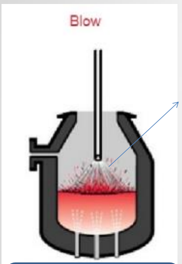


Charging takes a couple of minutes.

Then the vessel is rotated back to the vertical position and lime/dolomite fluxes are dropped onto the charge from overhead bins while the lance is lowered to a few feet above the bottom of the vessel.

The lance is water-cooled with a multi-hole copper tip. Through this lance, oxygen of greater than 99.5% purity is blown into the mix. If the oxygen is lower in purity, nitrogen levels at tap become unacceptable.

2-Blow



Blasting oxygen

Oxygen combines exothermically with C,Si ,Mn, P

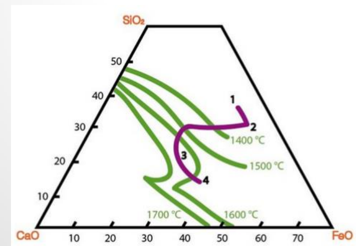
Chemical Reactions:

- C + ½ O2→ CO
- CO+ 1/2O2→ CO2

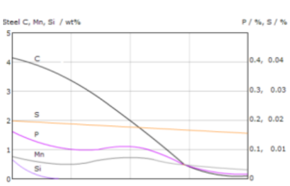
$CO_2/(CO+CO_2)$: Post Combustion ratio

- Si+ O2 → SiO2
- 2P+ 5/2O2 → P2O5
- Mn+ ½ O2 → MnO
- Fe+ ½O2 → FeO
- 2Fe+ 3/2O2 → Fe2O3

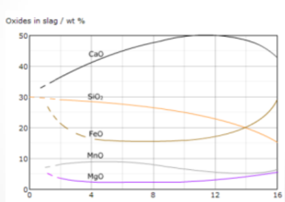
- Slag composition: SiO2-P2O5-FeO-MnO
- Flux composition: Ca0- MgO
- Refractory wear: MgO



Changes in Metal Composition



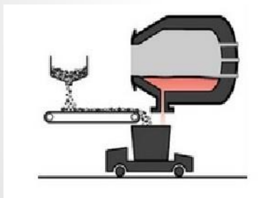
Changes in Slag composition



Lining Protection Techniques:

- Avoid the most aggressive slag
- Protective slag coating
- Local repairs

3-Tapping and Additions



Tapping

- After blowing, purified steel is poured into ladles

Typical composition of the blown steel

C	Mn	Si	S	P
0.3-0.9%	0.05-0.1%	0.001-0.003%	0.01-0.03%	0.005-0.03%

Additions

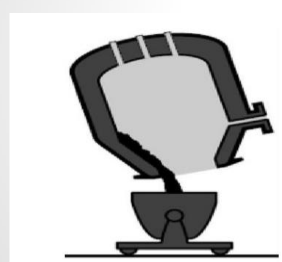
- It is needed to further purifications according to customer requirements

- Further purifications are done by alloy additives

Some Common additives;

	Mn	C	Si	Fe
ferromanganese	80%	6%	-	balance
silicomanganese	66%	2%	16%	balance
ferrosilicon	-	-	75%	balance

4-Slagging



Basic Oxygen Furnace During Slagging Operation

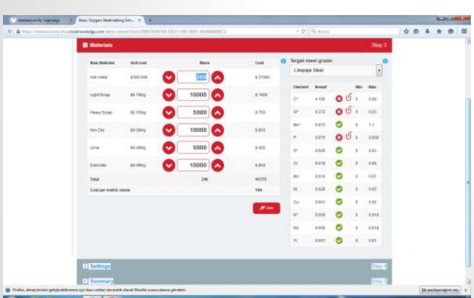
Slagging

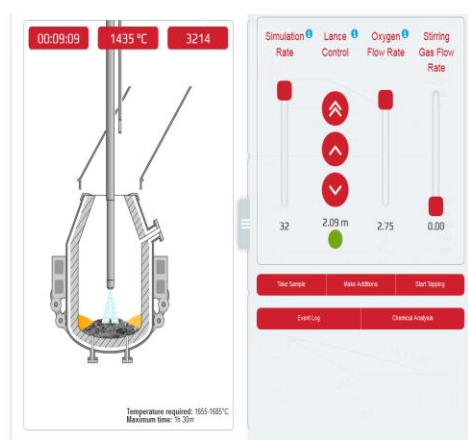
- After tapping, slag remains in the BOF vessel
- The slag is poured into slag pots

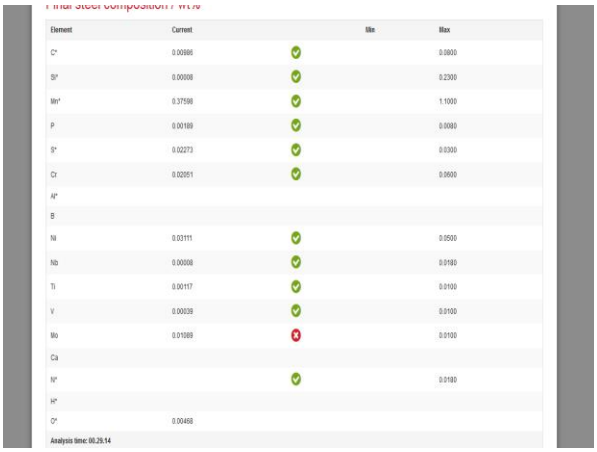
What is the current situation in Turkey today ?

SIMULATION

First Trial

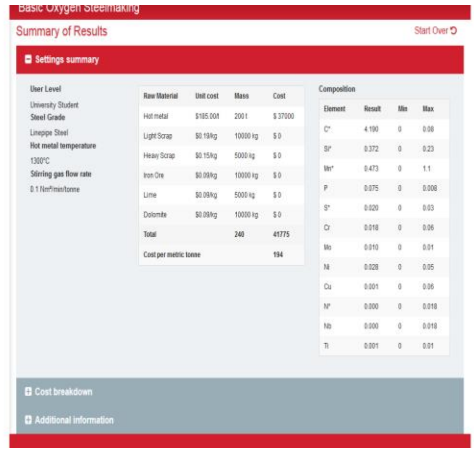






Element	Current		Min	Max
C*	0.00986	✓		0.0800
Si*	0.00008	✓		0.2300
Mn*	0.37598	✓		1.1000
P	0.00189	✓		0.0080
S*	0.02273	✓		0.0300
Cr	0.02051	✓		0.0600
Al*				
B				
Ni	0.03111	✓		0.0500
Nb	0.00008	✓		0.0180
Ti	0.00117	✓		0.0100
V	0.00039	✓		0.0100
Mo	0.01089	✗		0.0100
Ca				
N*		✓		0.0180
H*				
O*	0.00468			

Analysis time: 00.29.14



Basic Oxygen Steelmaking

Summary of Results

Start Over

Settings summary

User Level

University Student

Steel Grade

Linepipe Steel

Hot metal temperature

1300°C

Stirring gas flow rate

0.1 Nm³/min/tonne

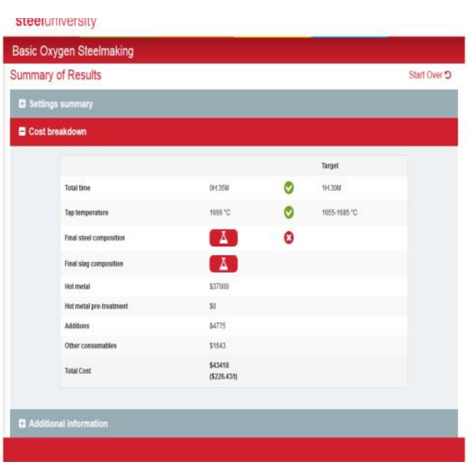
Raw Material	Unit cost	Mass	Cost
Hot metal	$185.00/t	200 t	$ 37000
Light Scrap	$0.19/kg	10000 kg	$ 0
Heavy Scrap	$0.15/kg	5000 kg	$ 0
Iron Ore	$0.09/kg	10000 kg	$ 0
Lime	$0.09/kg	5000 kg	$ 0
Dolomite	$0.09/kg	10000 kg	$ 0
Total		240	41775
Cost per metric tonne			194

Composition

Element	Result	Min	Max
C*	4.190	0	0.08
Si*	0.372	0	0.23
Mn*	0.473	0	1.1
P	0.075	0	0.008
S*	0.020	0	0.03
Cr	0.018	0	0.06
Mo	0.010	0	0.01
Ni	0.028	0	0.05
Cu	0.001	0	0.06
N*	0.000	0	0.018
Nb	0.000	0	0.018
Ti	0.001	0	0.01

Cost breakdown

Additional information



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Basic Oxygen Steelmaking

Summary of Results

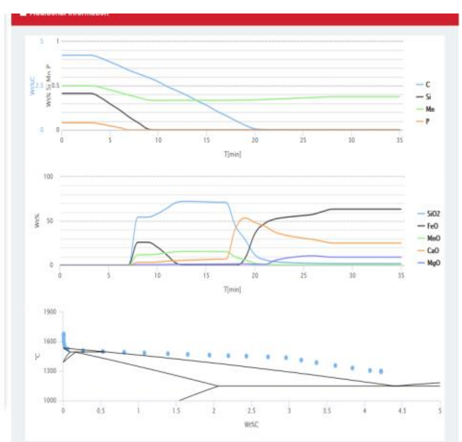
Start Over

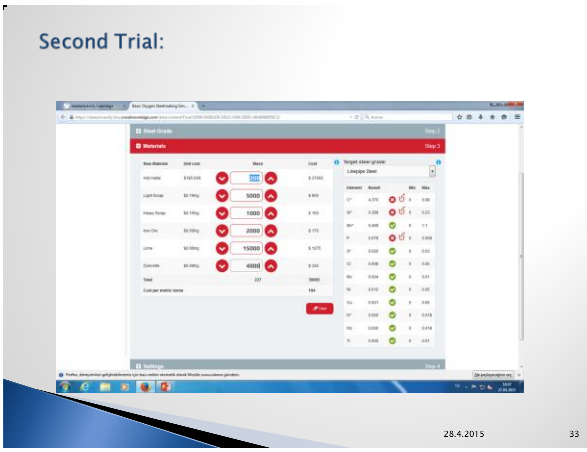
Settings summary

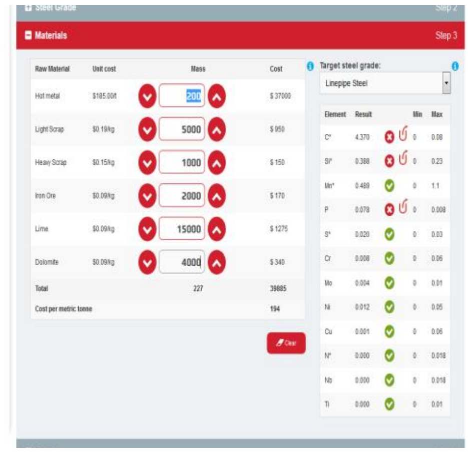
Cost breakdown

			Target
Total time	0H:35M	✓	1H:30M
Tap temperature	1666 °C	✓	1655-1685 °C
Final steel composition		✗	
Final slag composition			
Hot metal	$37000		
Hot metal pre-treatment	$0		
Additions	$4775		
Other consumables	$1643		
Total Cost	$43418 ($226.43/t)		

Additional information

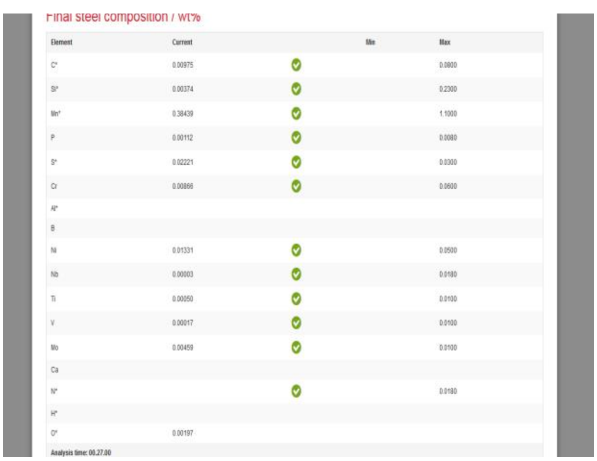






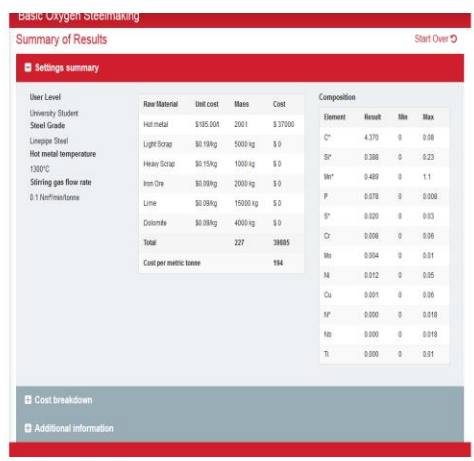
Raw Material	Unit cost	Mass	Cost
Hot metal	$185.00/t	200	$ 37000
Light Scrap	$0.19/kg	5000	$ 950
Heavy Scrap	$0.15/kg	1000	$ 150
Iron Ore	$0.09/kg	2000	$ 170
Lime	$0.09/kg	15000	$ 1275
Dolomite	$0.09/kg	4000	$ 340
Total		227	39885
Cost per metric tonne			194

Element	Result	Min	Max
C*	4.370	0	0.08
Si*	0.388	0	0.23
Mn*	0.489	0	1.1
P	0.078	0	0.008
S*	0.020	0	0.03
Cr	0.008	0	0.06
Mo	0.004	0	0.01
Ni	0.012	0	0.05
Cu	0.001	0	0.06
N*	0.000	0	0.018
Nb	0.000	0	0.018
Ti	0.000	0	0.01



Element	Current	Min	Max
C*	0.00975		0.0800
Si*	0.00374		0.2300
Mn*	0.38439		1.1000
P	0.00112		0.0080
S*	0.02221		0.0300
Cr	0.00866		0.0600
Al*			
B			
Ni	0.01331		0.0500
Nb	0.00003		0.0180
Ti	0.00050		0.0100
V	0.00017		0.0100
Mo	0.00459		0.0100
Ca			
N*			0.0180
H*			
O*	0.00197		

Analysis time: 00.27.00



Raw Material	Unit cost	Mass	Cost
Hot metal	$185.00/t	200 t	$ 37000
Light Scrap	$0.19/kg	5000 kg	$ 0
Heavy Scrap	$0.15/kg	1000 kg	$ 0
Iron Ore	$0.09/kg	2000 kg	$ 0
Lime	$0.09/kg	15000 kg	$ 0
Dolomite	$0.09/kg	4000 kg	$ 0
Total		227	39885
Cost per metric tonne			194

Element	Result	Min	Max
C*	4.370	0	0.08
Si*	0.388	0	0.23
Mn*	0.489	0	1.1
P	0.078	0	0.008
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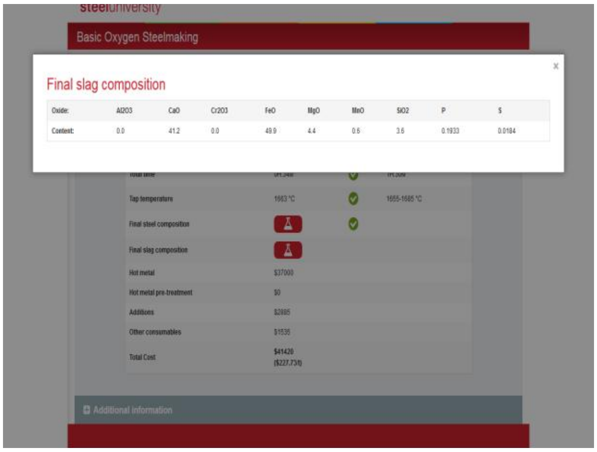
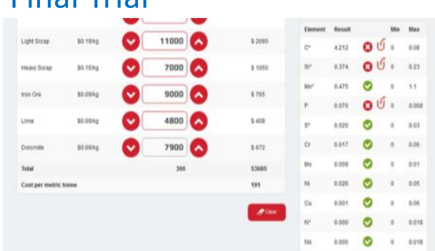
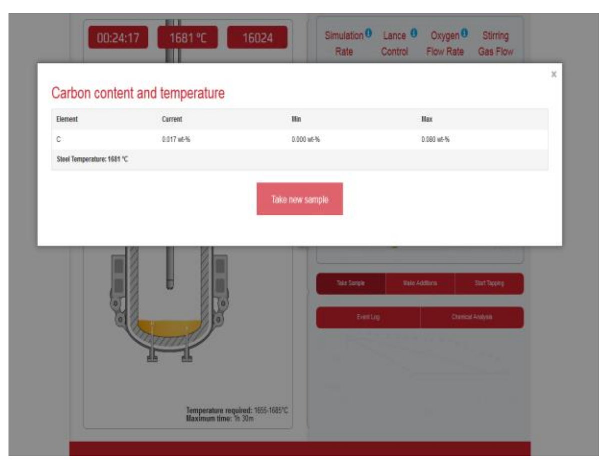
Mo	0.004	0	0.01
Ni	0.012	0	0.05
Cu	0.001	0	0.06
N*	0.000	0	0.018
Nb	0.000	0	0.018
Ti	0.000	0	0.01

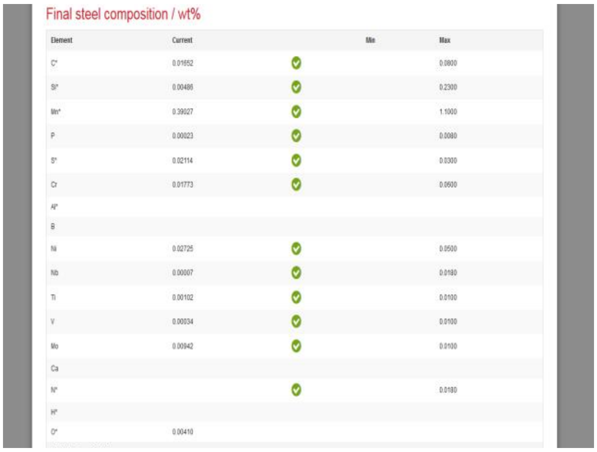


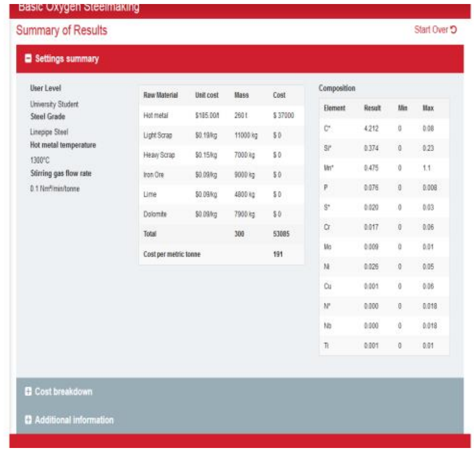
Final Trial

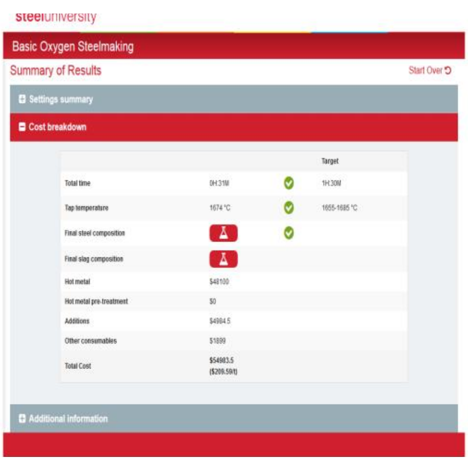


Hot Metal Temperature = 1300 Celcius,
Bottom Stirring Gas Flow Rate= 0.1 (Nitrogen)




Final steel composition / wt%
Element Current Min Max
C* 0.01652 0.0800
Si* 0.00486 0.2300
Mn* 0.39027 1.1000
P 0.00023 0.0080
S* 0.02114 0.0300
Cr 0.01773 0.0600
Al*
B
Ni 0.02725 0.0500
Nb 0.00007 0.0180
Ti 0.00102 0.0100
V 0.00034 0.0100
Mo 0.00942 0.0100
Ca
N* 0.0180
H*
O* 0.00410


Summary of Results
Start Over
Settings summary
User Level
University Student
Steel Grade
Linepipe Steel
Hot metal temperature
1300°C
Stirring gas flow rate
0.1 Nm³/min/tonne
Raw Material Unit cost Mass Cost
Hot metal $185.00/t 260 t $ 37000
Light Scrap $0.19/kg 11000 kg $ 0
Heavy Scrap $0.15/kg 7000 kg $ 0
Iron Ore $0.09/kg 9000 kg $ 0
Lime $0.09/kg 4800 kg $ 0
Dolomite $0.09/kg 7900 kg $ 0
Total 300 53085
Cost per metric tonne 191
Composition
Element Result Min Max
C* 4.212 0 0.08
Si* 0.374 0 0.23
Mn* 0.475 0 1.1
P 0.076 0 0.008
S* 0.020 0 0.03
Cr 0.017 0 0.06
Mo 0.009 0 0.01
Ni 0.026 0 0.05
Cu 0.001 0 0.06
N* 0.000 0 0.018
Nb 0.000 0 0.018
Ti 0.001 0 0.01
Cost breakdown
Additional information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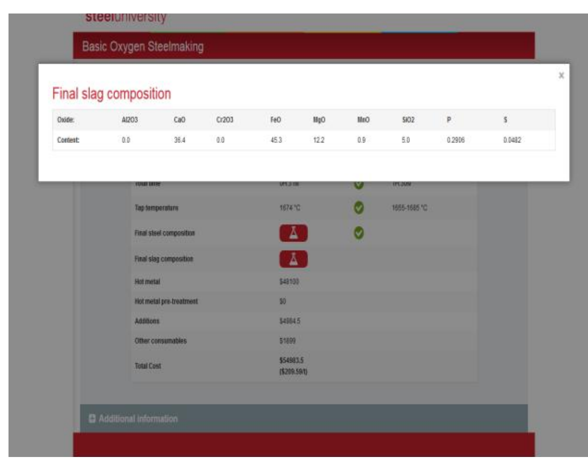
Basic Oxygen Steelmaking
Summary of Results
Start Over
Settings summary
Cost breakdown
Target
Total time 0H:31M 1H:30M
Tap temperature 1674 °C 1655-1685 °C
Final steel composition
Final slag composition
Hot metal $48100
Hot metal pre-treatment $0
Additions $4984.5
Other consumables $1899
Total Cost $54983.5 ($209.59/t)
Additional information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Basic Oxygen Steelmaking
Final slag composition
Oxide: Al2O3 CaO Cr2O3 FeO MgO MnO SiO2 P S
Content: 0.0 36.4 0.0 45.3 12.2 0.9 5.0 0.2906 0.0482
Tap temperature 1674 °C 1655-1685 °C
Final steel composition
Final slag composition
Hot metal $48100
Hot metal pre-treatment $0
Additions $4984.5
Other consumables $1899
Total Cost $54983.5 ($209.59/t)
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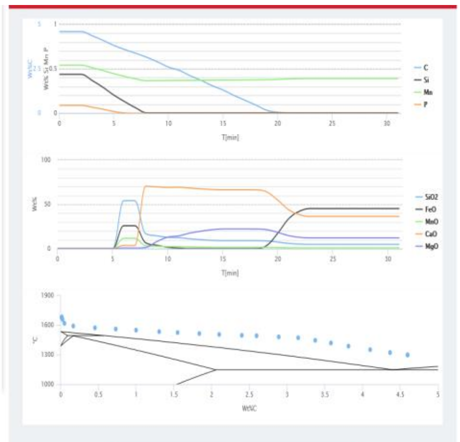

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- https://steeluniversity.lms.crossknowledge.com/data/content/Final/1264/3A8ACA74-B2D5-28CC-80F6-0FBEFB29E683/index.html#gotoExercise=1122
- https://www.steel.org/Making%20Steel/How%20Its%20Made/Processes/Processes%20Info/The%20Basic%20Oxygen%20Steelmaking%20Process.aspx

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