Durgapur Steel Plant

TRAINING MODULE ON STEEL MELTING SHOP & QUALITY

FOR MTT BATCH

BINOD KUMAR PADHI, SR MGR, RCL

Product Segment & Key Customers

CONSTRUCTION

TMT Bars
Fe500D,550D,
600, SAIL SeQR

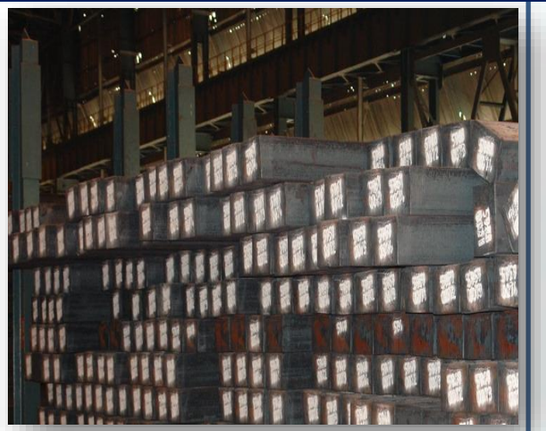
TRANSPORTATION

Wheel & Axles
LOCO, COACH &
LHB

INFRASTRUCTURE

Light & Medium Structurals
Bridge, High rise

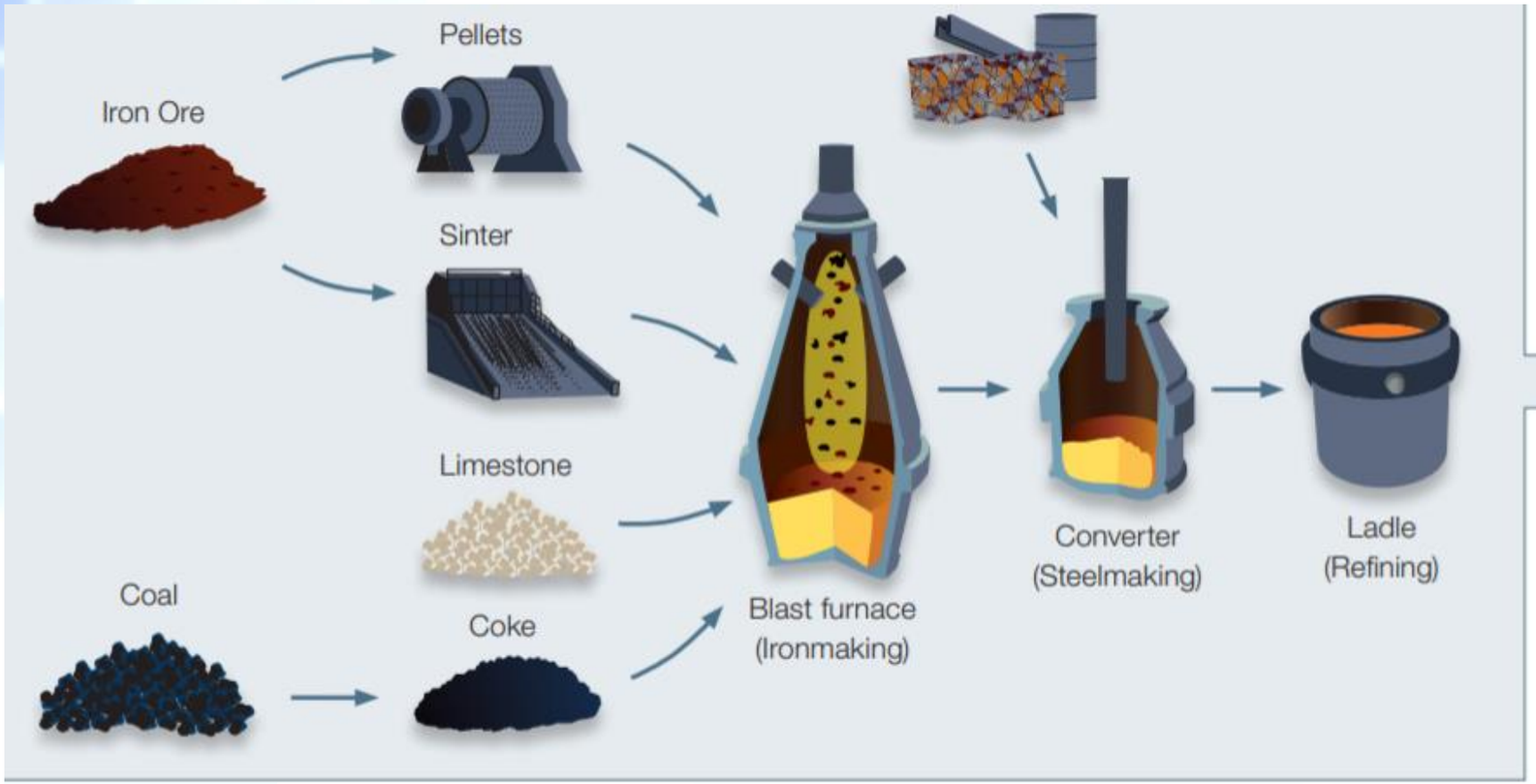
ENERGY

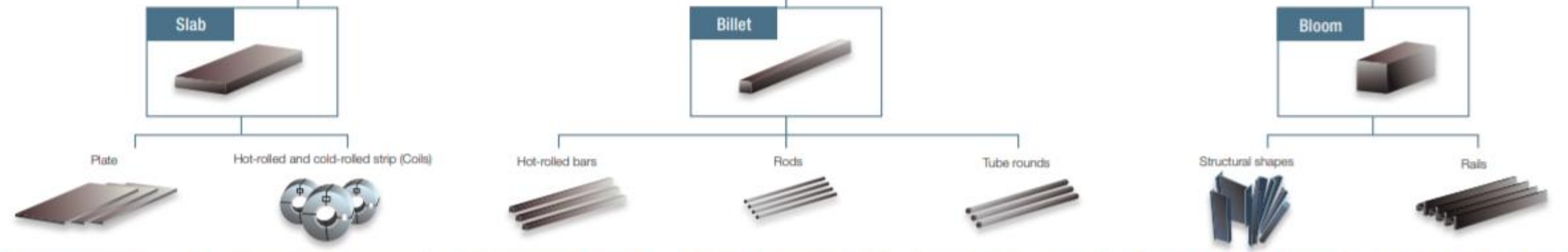


Blooms & Billets
For re-rollers :
TLT , Wire rods etc

SKIPPER Limited
R.S. Infraprojects Pvt. Ltd.
SANVIJAY ROLLING & ENGINEERING LTD
TATA PROJECTS LIMITED
BHEL
Kolkata Metro Railway
L&T
NCC Limited
SIMPLEX INFRASTRUCTURES LTD.
AVON STEEL INDUSTRIES PVT. LTD.
NTPC
हर एक काम देश के नाम

Integrated Steel plant process



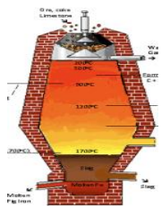


हर एक काम देश के नाम

Composition of Hot Metal & Steel

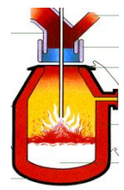
I S

Hot Metal



- ✓ Carbon: 4%-5.5%
- ✓ Sulfur: 300 to 800 ppm
- ✓ Phosphorous: up to 3000 ppm

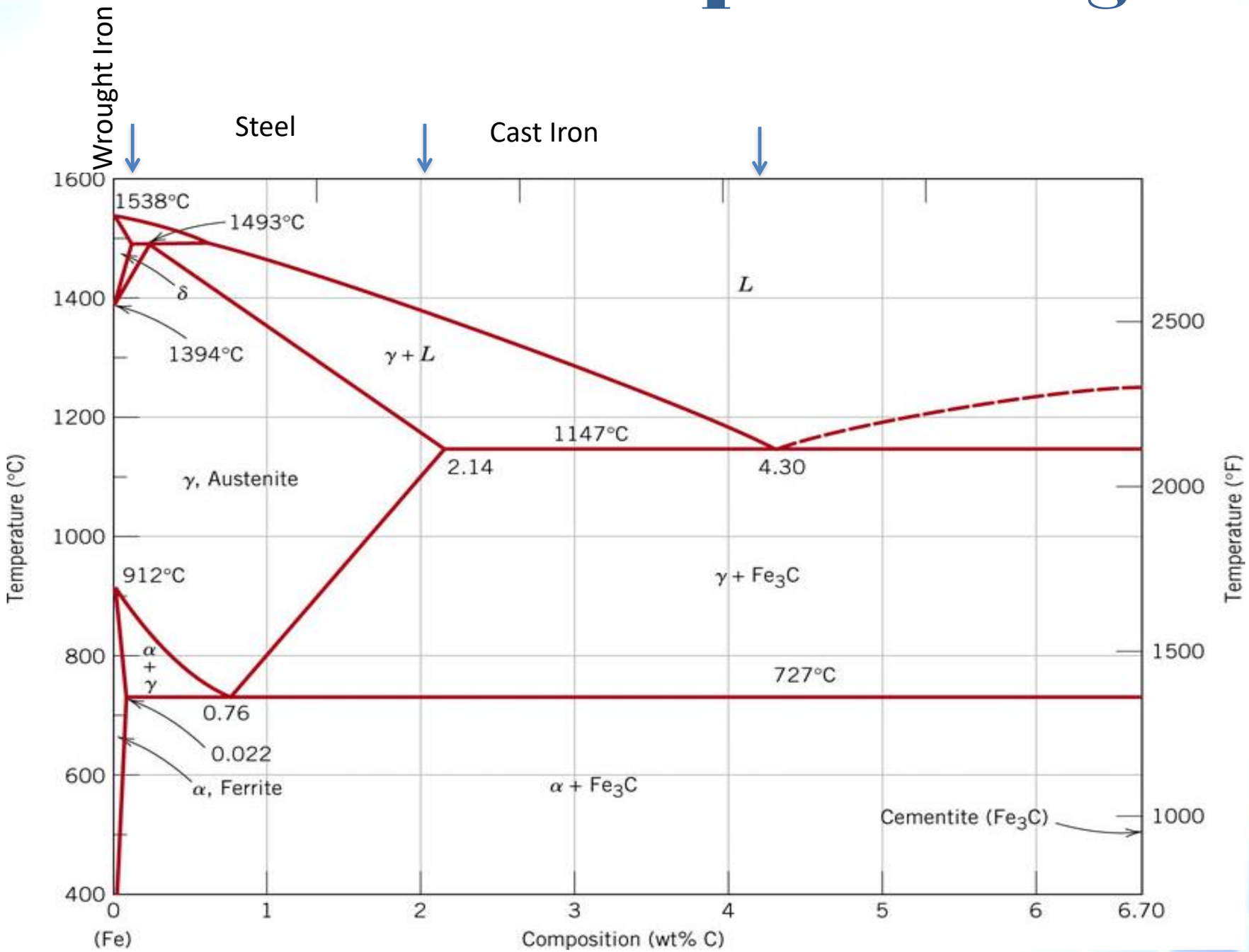
Steel (DSP)



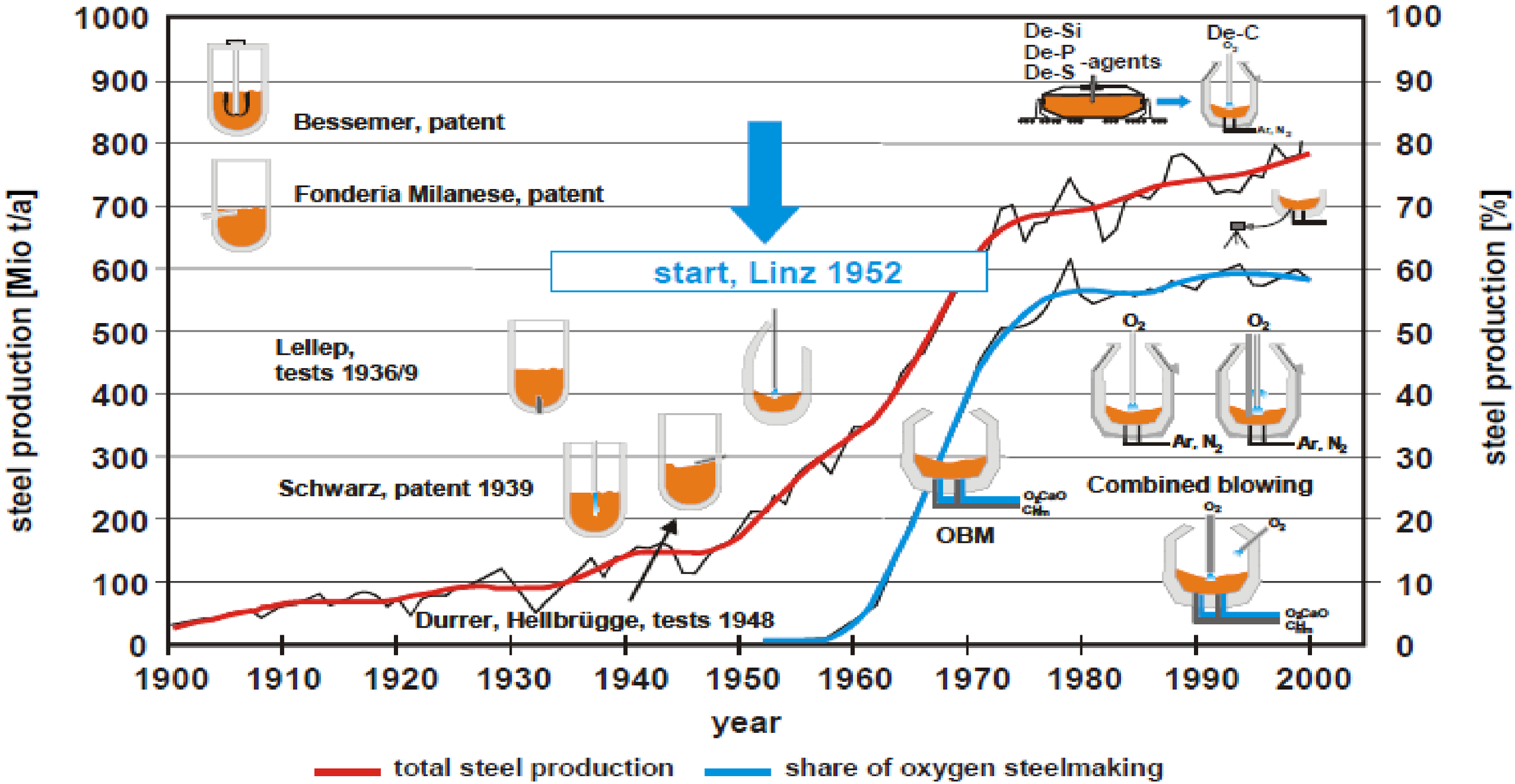
- ✓ Carbon: 0.07% to 0.67%
- ✓ Sulfur: 400ppm Max
- ✓ Phosphorous: 400ppm Max

हर एक काम देश के नाम

The Iron- Iron Carbide phase diagram



Evolution of steel making process



Evolution of quality steel making

LEVELS OF RESIDUALS (ppm)

Element	1900	2021
C	2100 (0.21%)	10
O_{tot}	130	5
H	-	0.8
S	690	5
N	35	15
P	450	<30

Measure of Cleanliness : Total oxygen

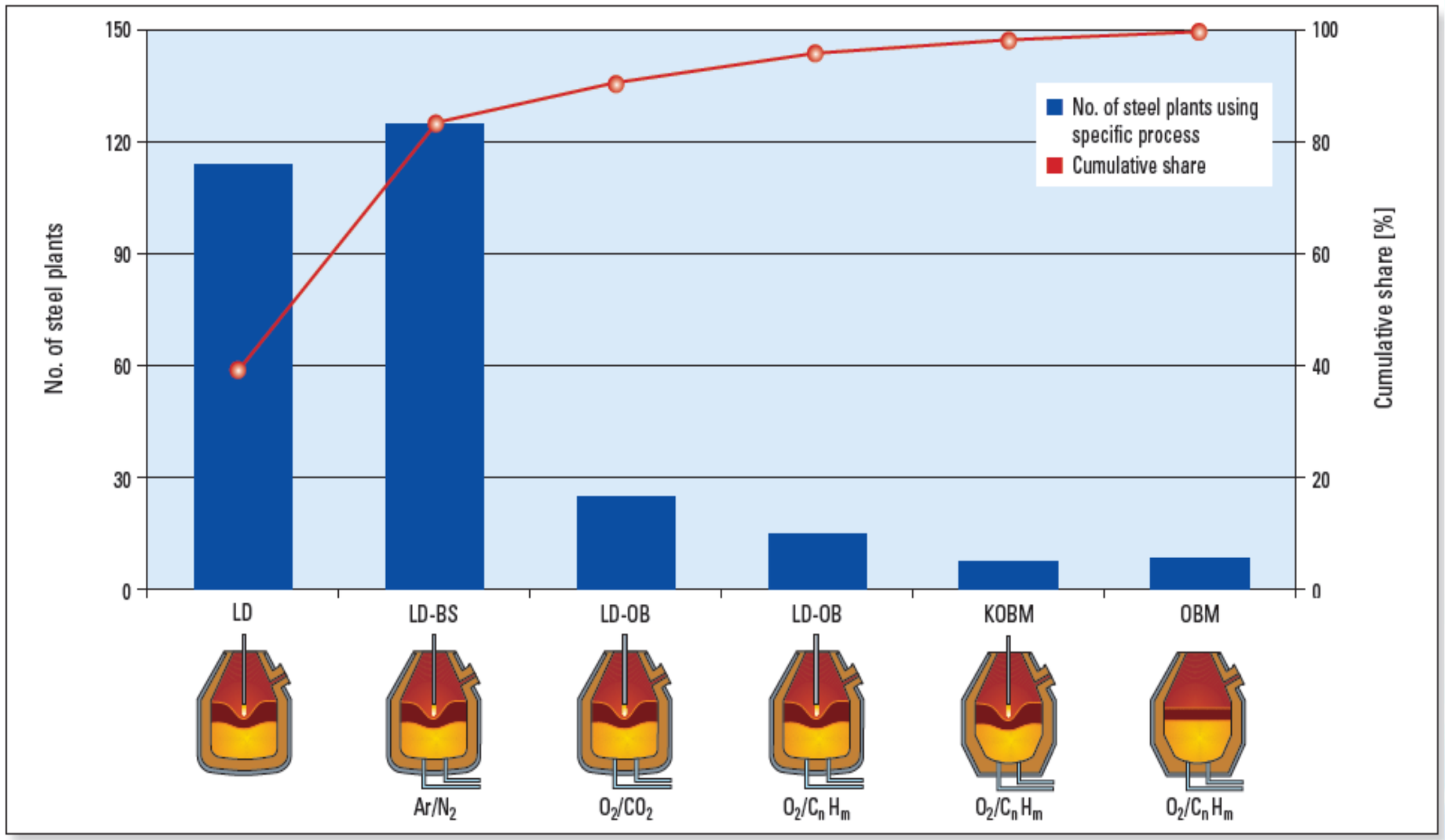
Cleanliness Requirements Reported for Steel Products

Product	Maximum impurity content		Maximum inclusion size
Line pipe	Total 0 : 30 ppm	N : 30 ppm	100 μm
Deep drawn sheet	Total 0 : 20 ppm	N : 30 ppm	100 μm
Heavy plate	Total 0 : 20 ppm	N : 30 ppm	Cluster 200 μm Single : 20 μm
Drawn & ironed can	Total 0 : 20 ppm	N : 30 ppm	20 μm
Wire	Total 0 : 30 ppm	N : 60 ppm	20 μm
Tire cord	Total 0 : 15 ppm	N : 40 ppm	15 μm
Bearing	Total 0 : 10 ppm		15 μm

Residuals in Special Steel

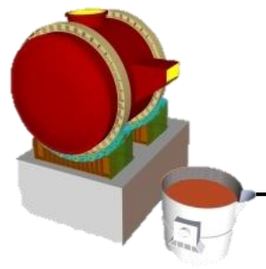
Product	Maximum impurity content		Inclusion volume, %
	Sulphur, %	Phos., %	
Higher Grade Line pipe	0.0005 – 0.0050	0.004 -0.010 H < 1.5	< 0.15
Deep drawn sheet	0.001-0.005	< 0.015 N :15-25ppm T.O. :20-30ppm	<0.15
Higher Grade CRNO	0.005 – 0.010	< 0.015 N < 40 ppm T.O. :20-30ppm	< 0.2
Defense Grade	< 0.010	< 0.015 H <2ppm	Low Vacuum treated

Share of steel plant by process

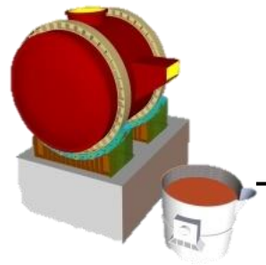


SMS shop process overview

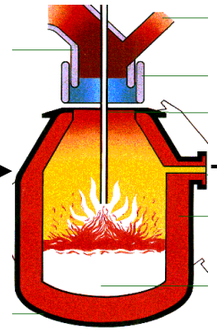
Hot Metal From BF



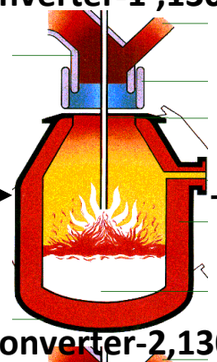
Mixer-1
1300T



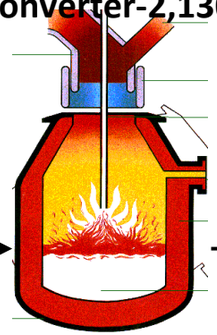
Mixer-2
1300T



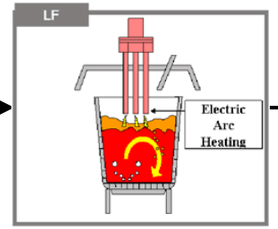
Converter-1 ,130 T

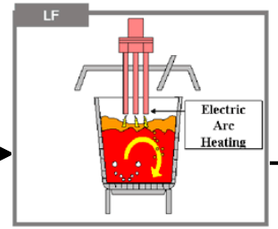


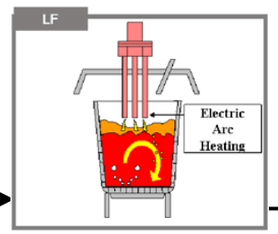
Converter-2,130 T



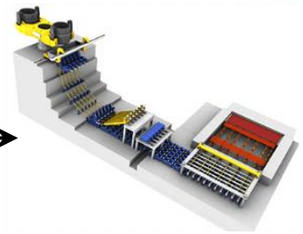
Converter-3,130 T



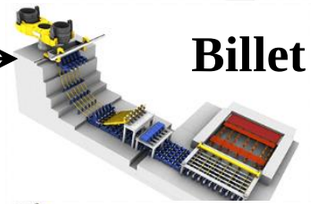




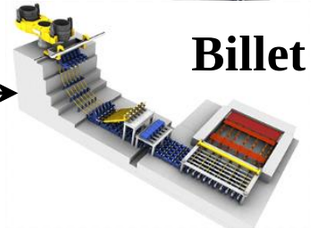
Ladle Furnaces



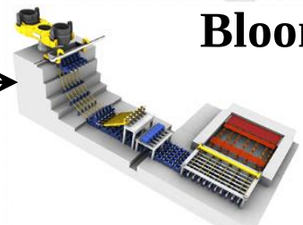
Billet Caster-1



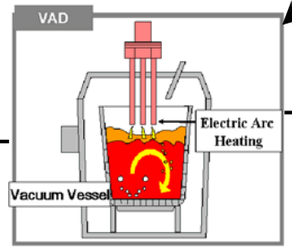
Billet Caster-2



Bloom Caster



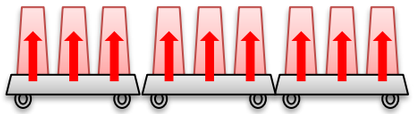
Bloom Cum Round caster



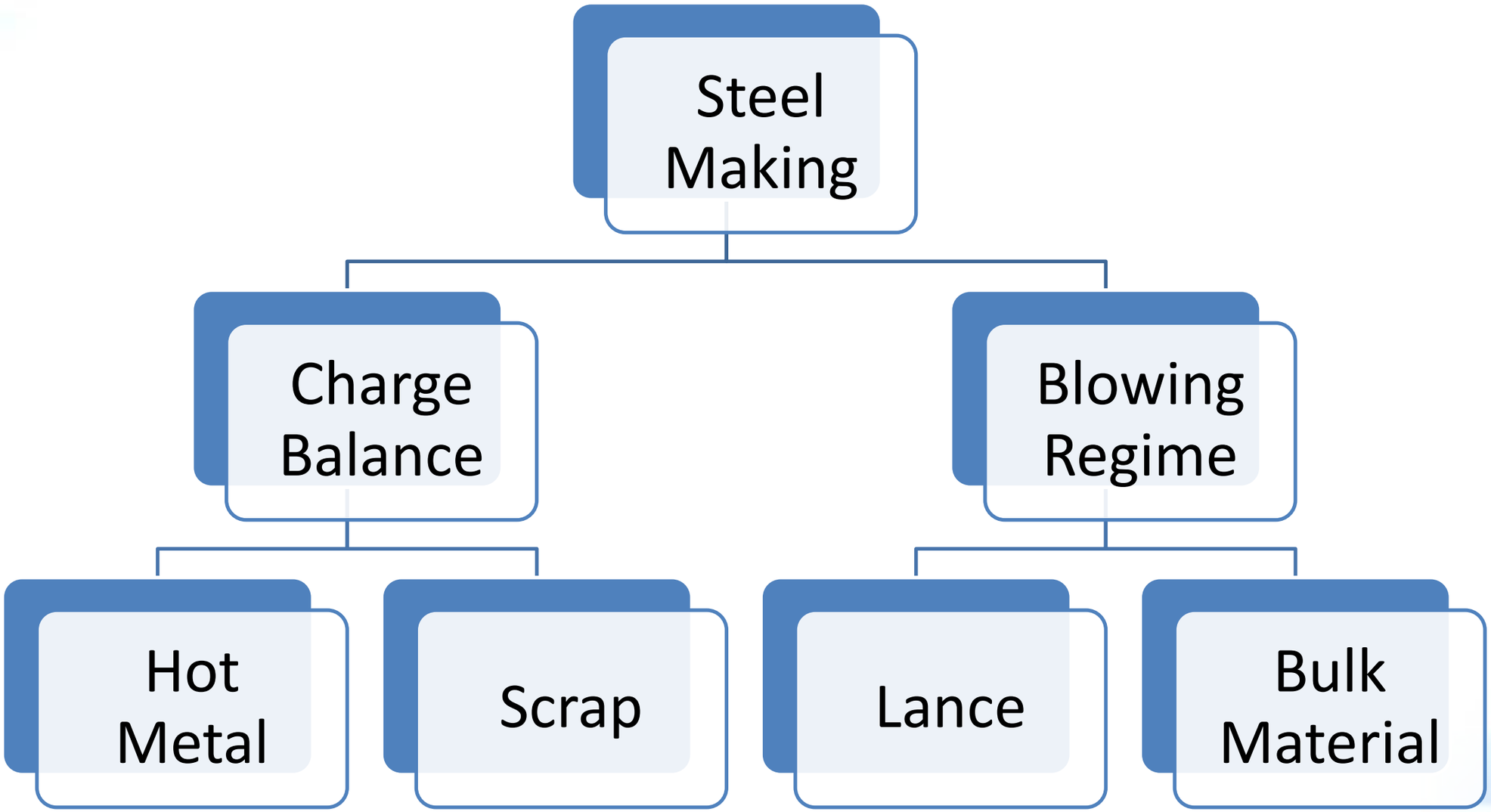
VAD

Casters

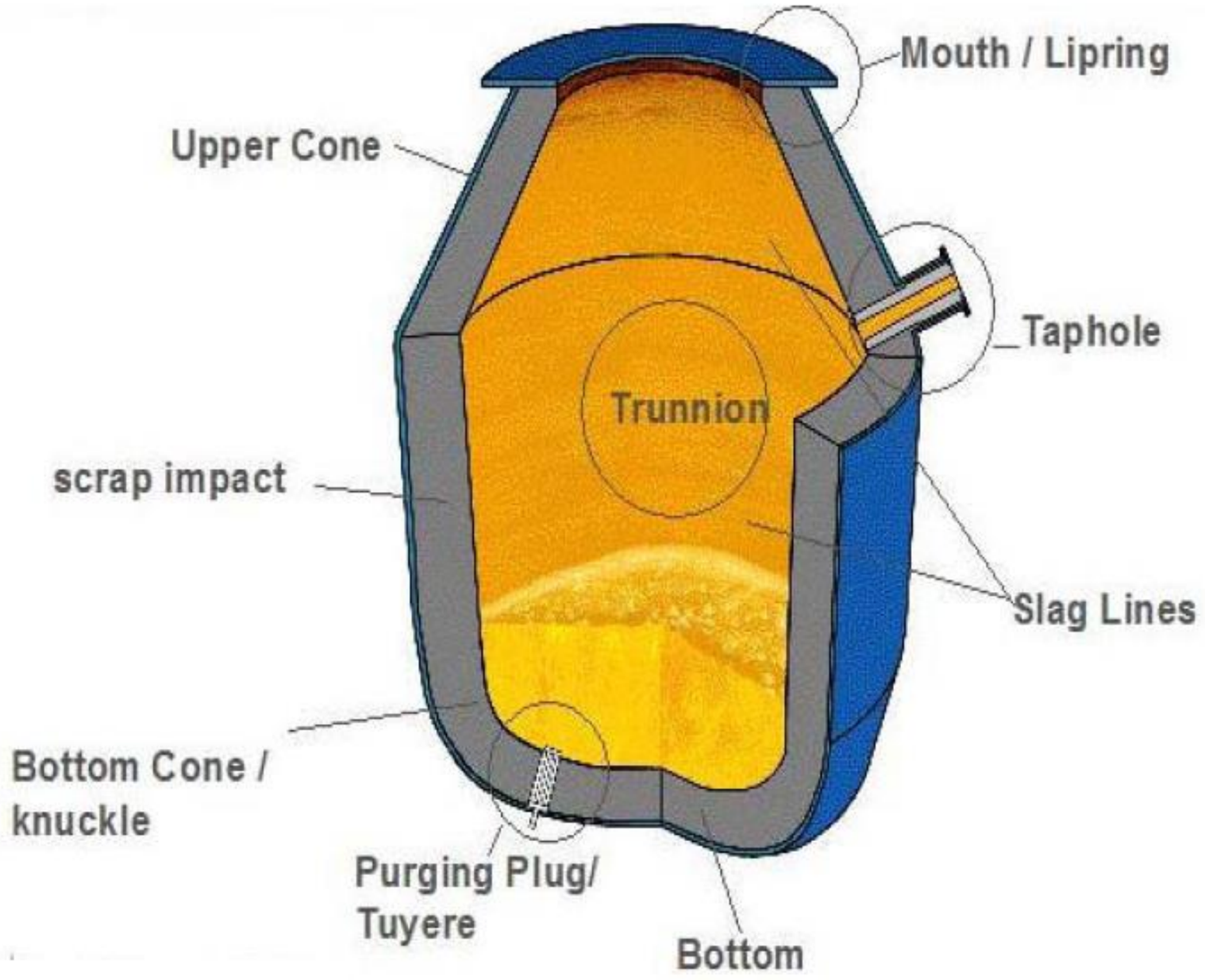
Bottom Pouring



BOF Steel making process



Schematic of BOF Converter

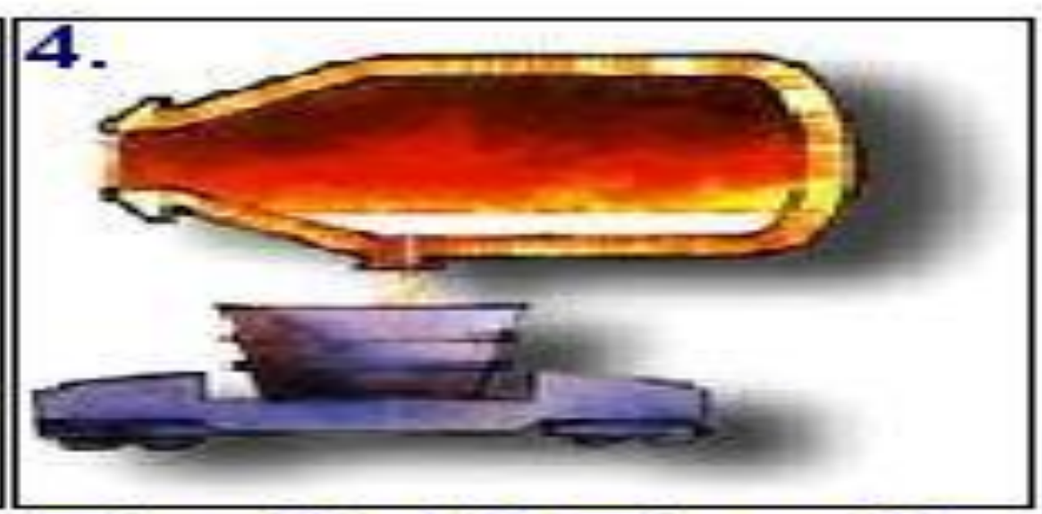


Stages of BOF process

Scrap Charge

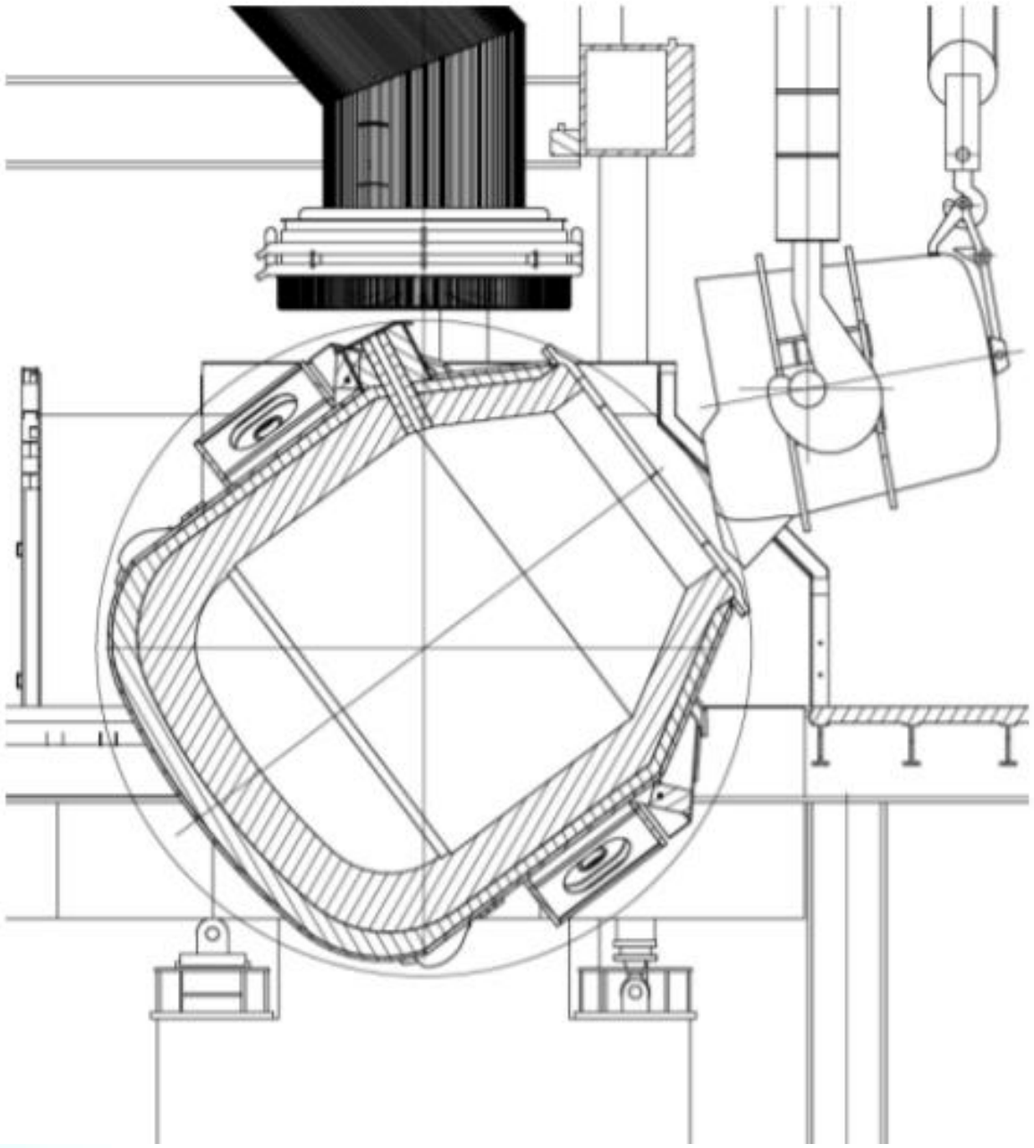
Hot Metal Charge

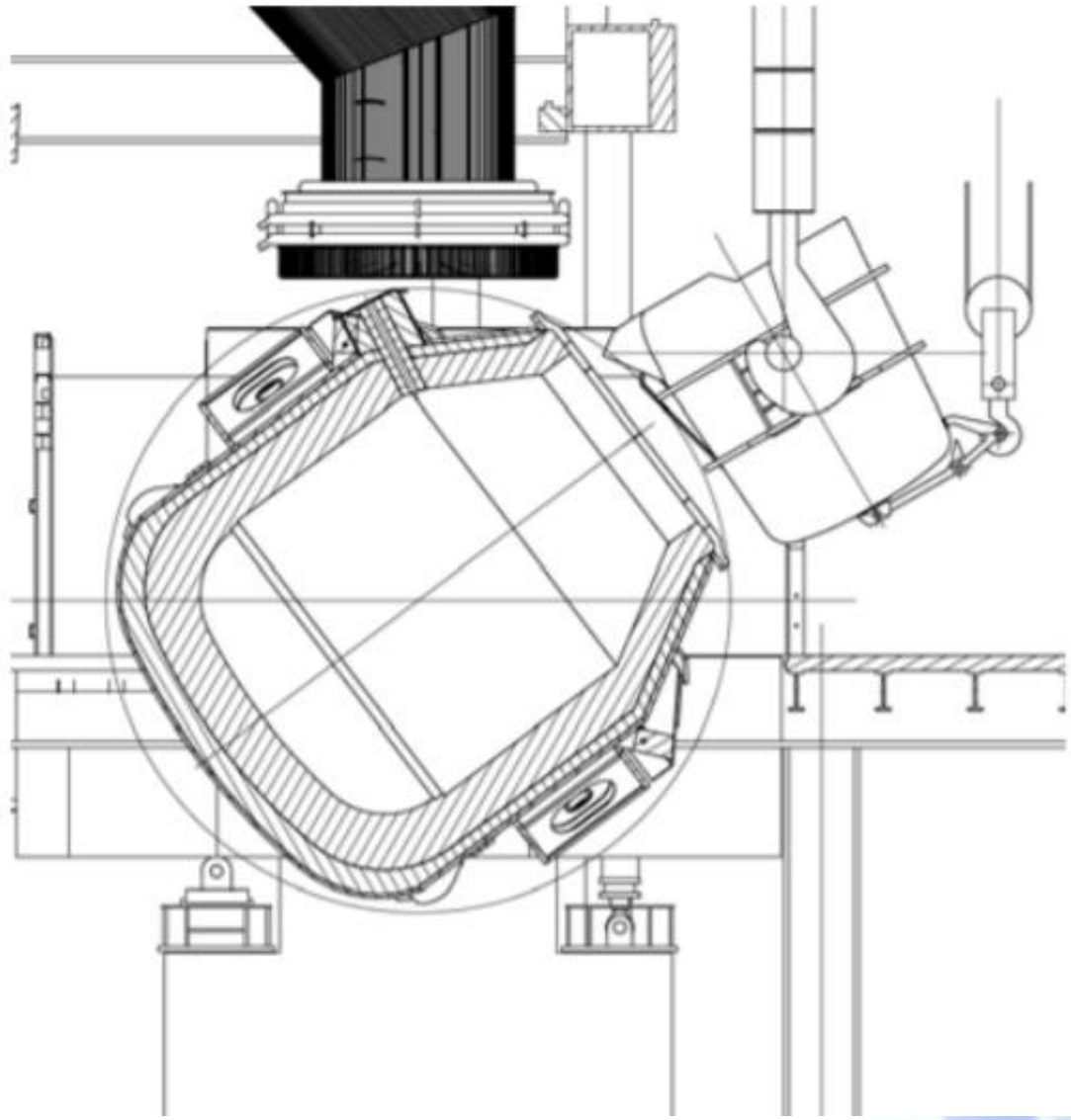
Oxygen Blowing



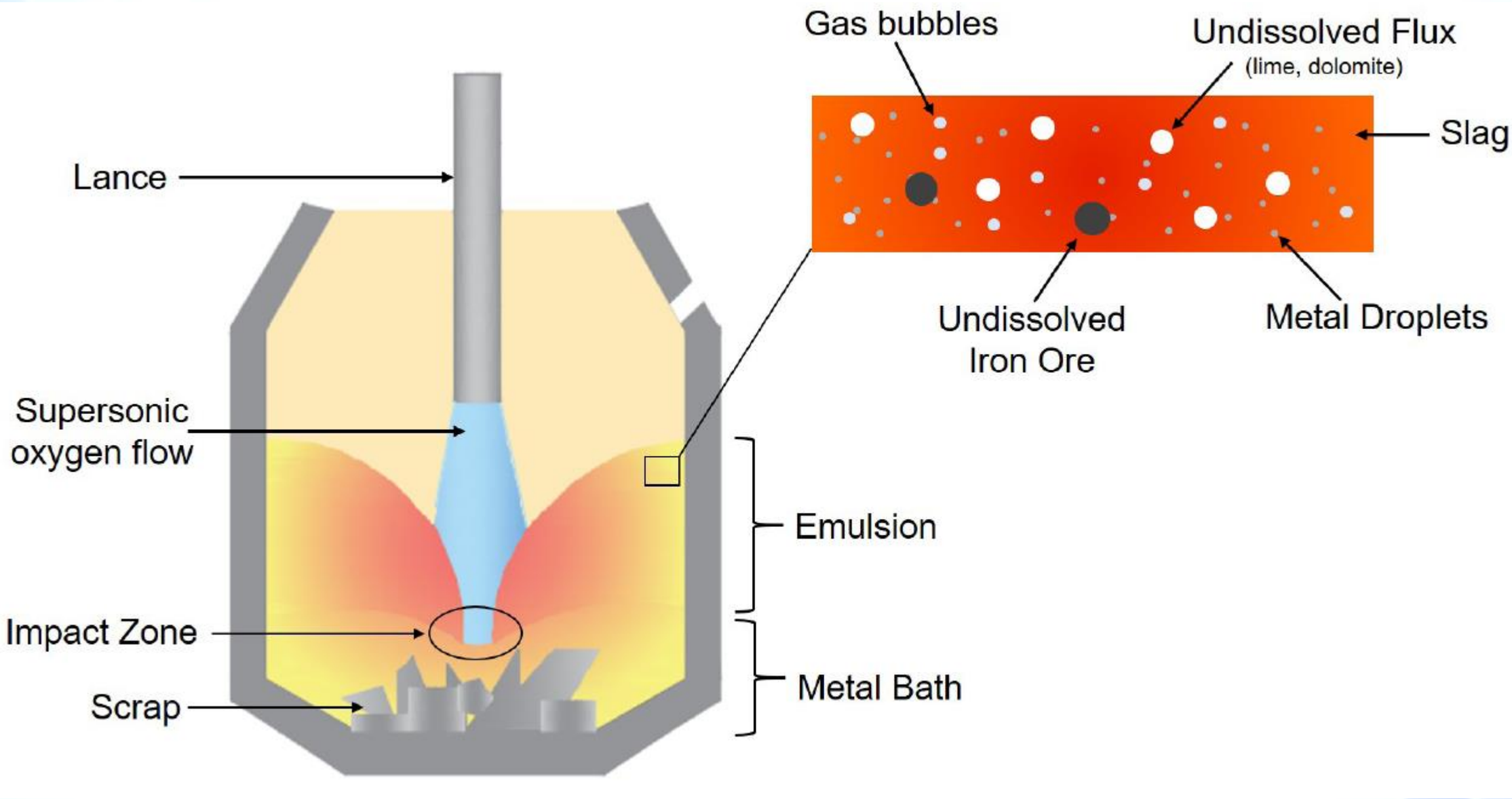
Tap Out & Transfer to Ladle Metallurgy Facility

GA of BOF converter charging

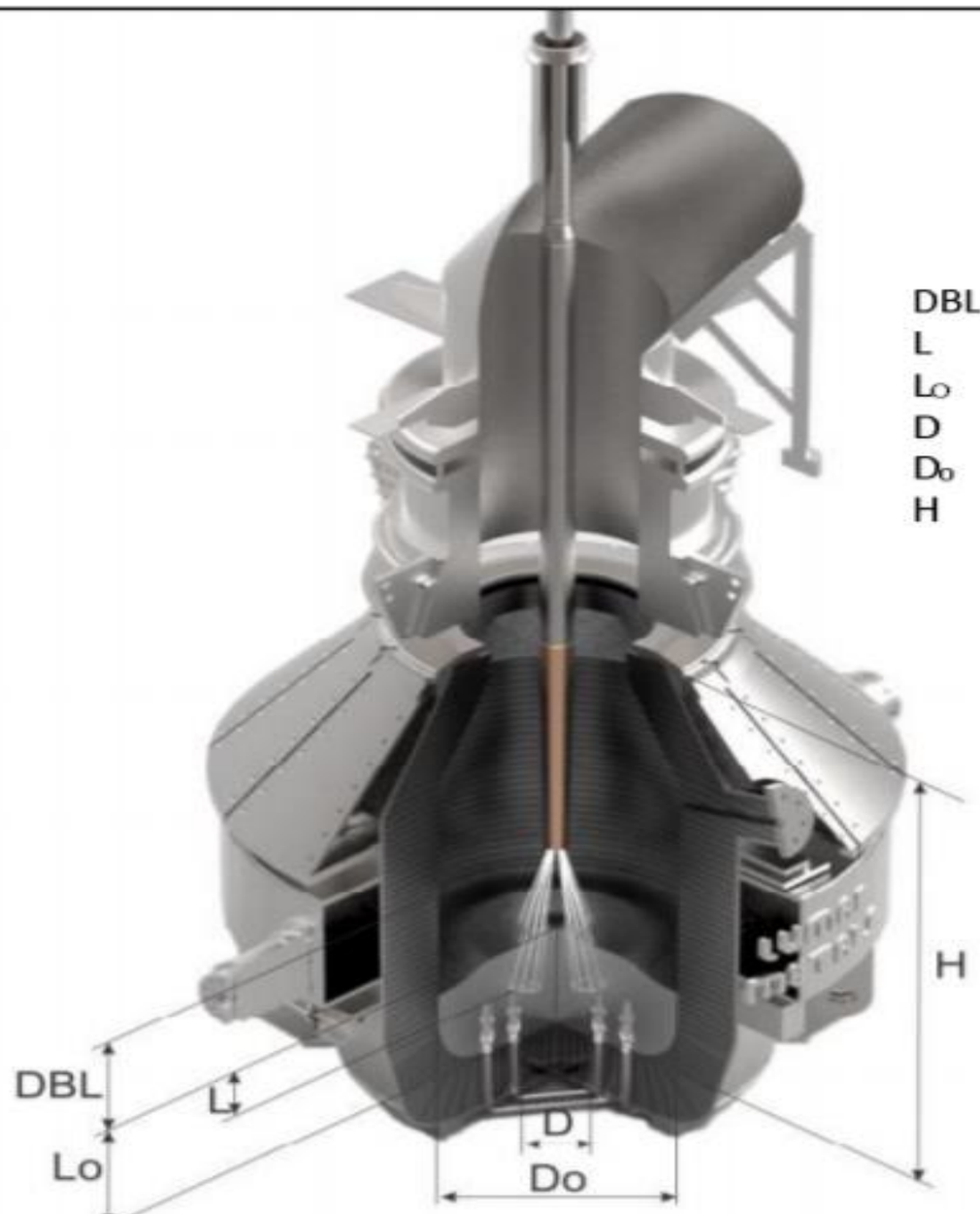




BOF blowing process



5 hole supersonic lanced design

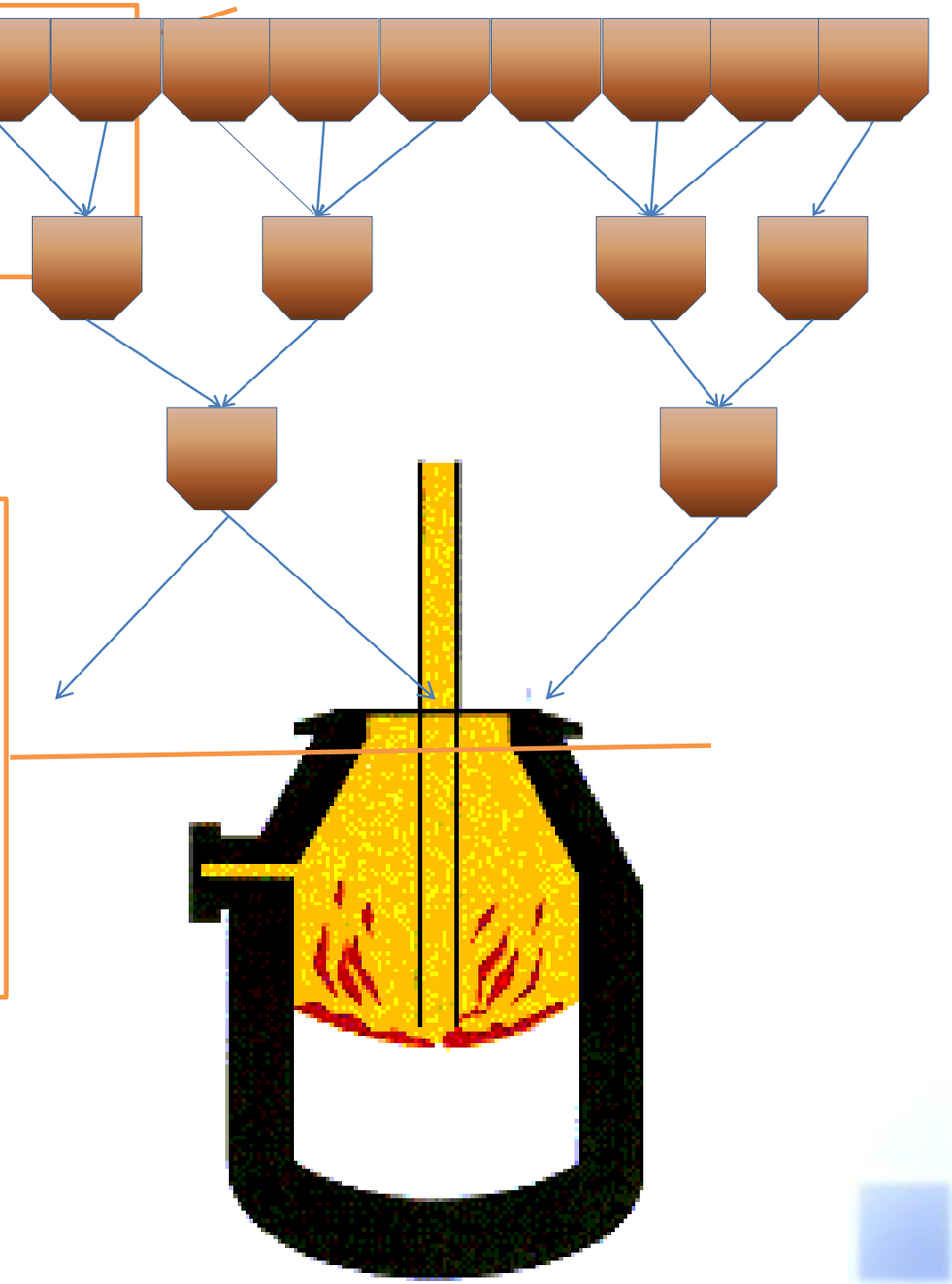


DBL - DISTANCE BATH LANCE
L - OXYGEN JET PENETRATION
L_O - STATIC BATH LEVEL
D - CAVITY DIAMETER
D_o - CONVERTER DIAMETER
H - INTERNAL HEIGHT CONVERTER

BOF technical parameters

- Fluxes
  - Lime From NLCP
  - CD from NDP
  - Iron Ore

- Oxygen From Oxygen Plant and BOO plant
- Pressure – 14 bar
- Flow rate – 370-400 nM3/min
- 5 Hole Lances, 1 running & 1 Standby, equipped with emergency Nitrogen lifting



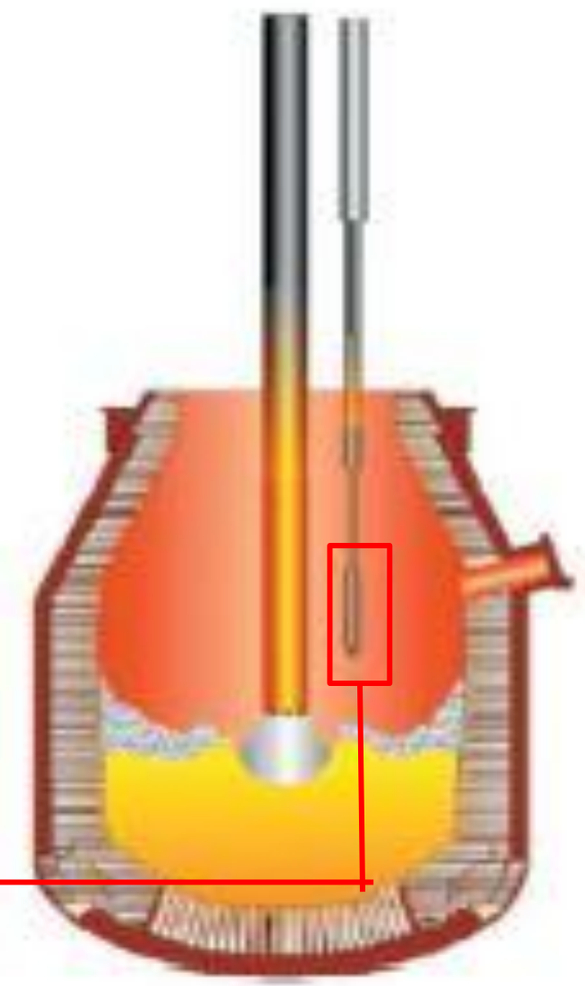
Concept of automatic steel making process

- Advanced slag control
- Bottom agitation
- Sub-lance
- Waste gas analyser
- Automatic slag detection and arrester
- Post combustion lance
- Slag-less lance

Sub Lance

Benefits:

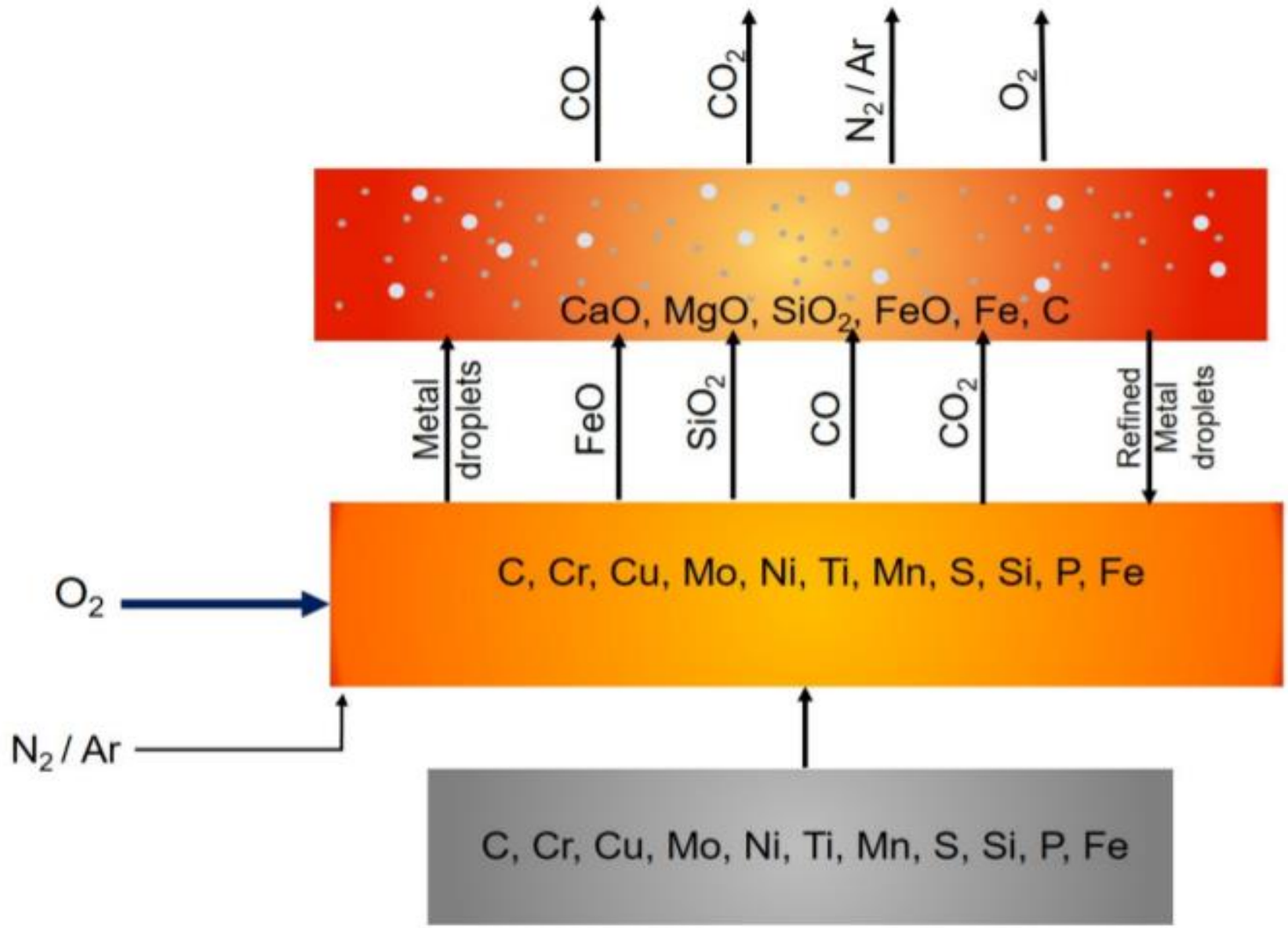
- Online and quick measurement of C, T, O, sample, bath ht.
- Helps to target the tapping temperature without interrupting the steel making process.
- Avoids frequent tilts of BOF Vessel for sample and temperature.
- Reduces tap to tap time

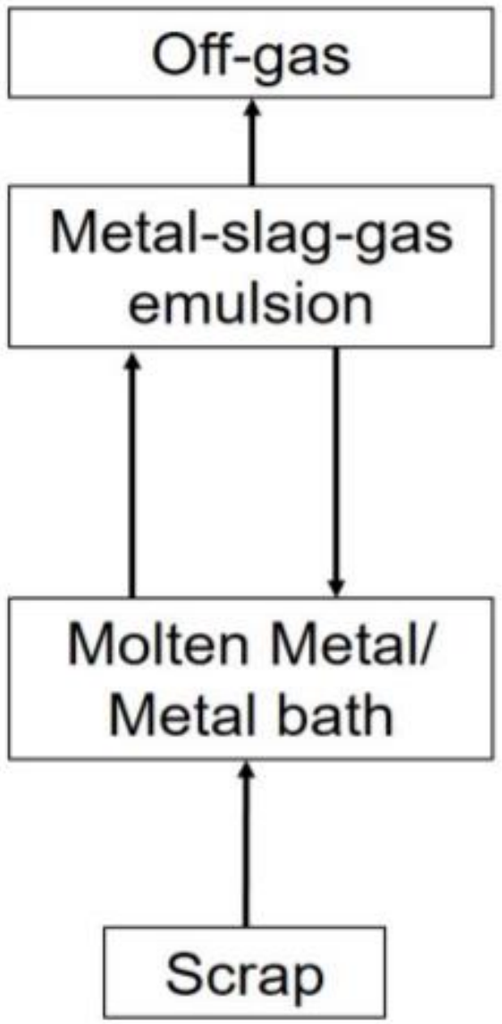


NLCP & NDP

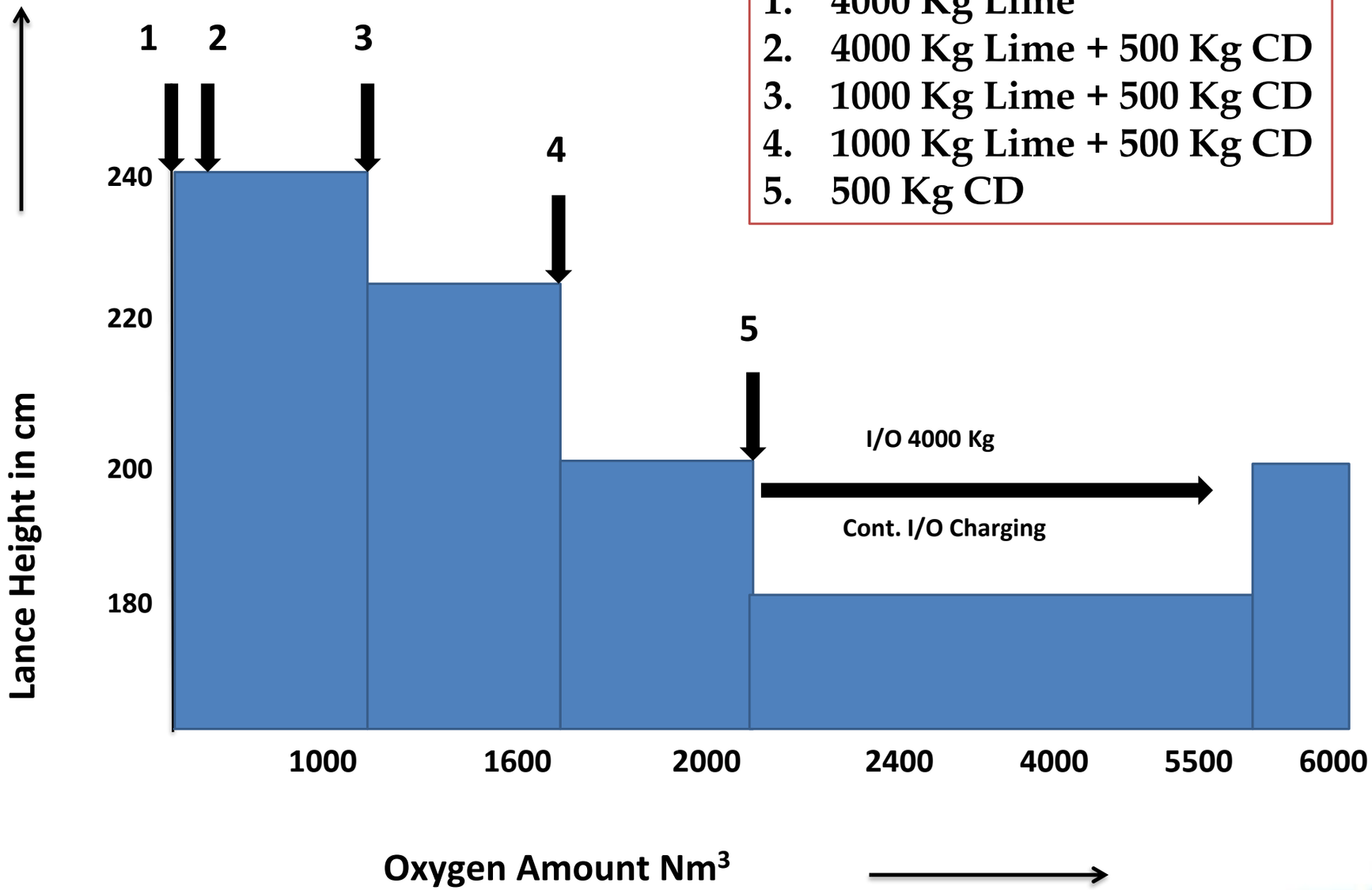
- 300 TPD Annular shaft Lime Kilns – 3
- 300 TPD Twin Shaft Dolomite Kiln – 1
- Conveyor system for the same

Reactions during BOF process





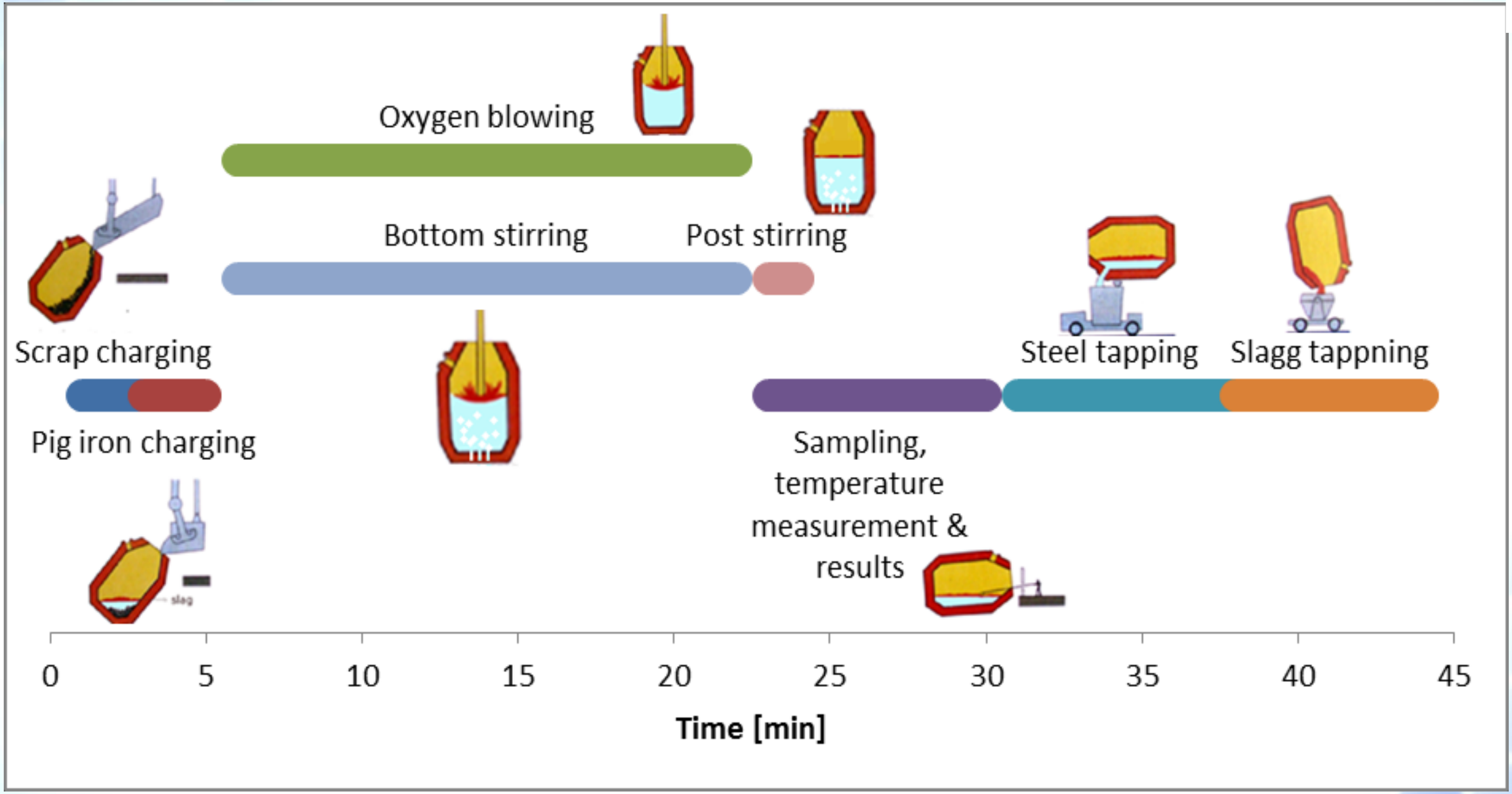
Blowing Pattern at DSP



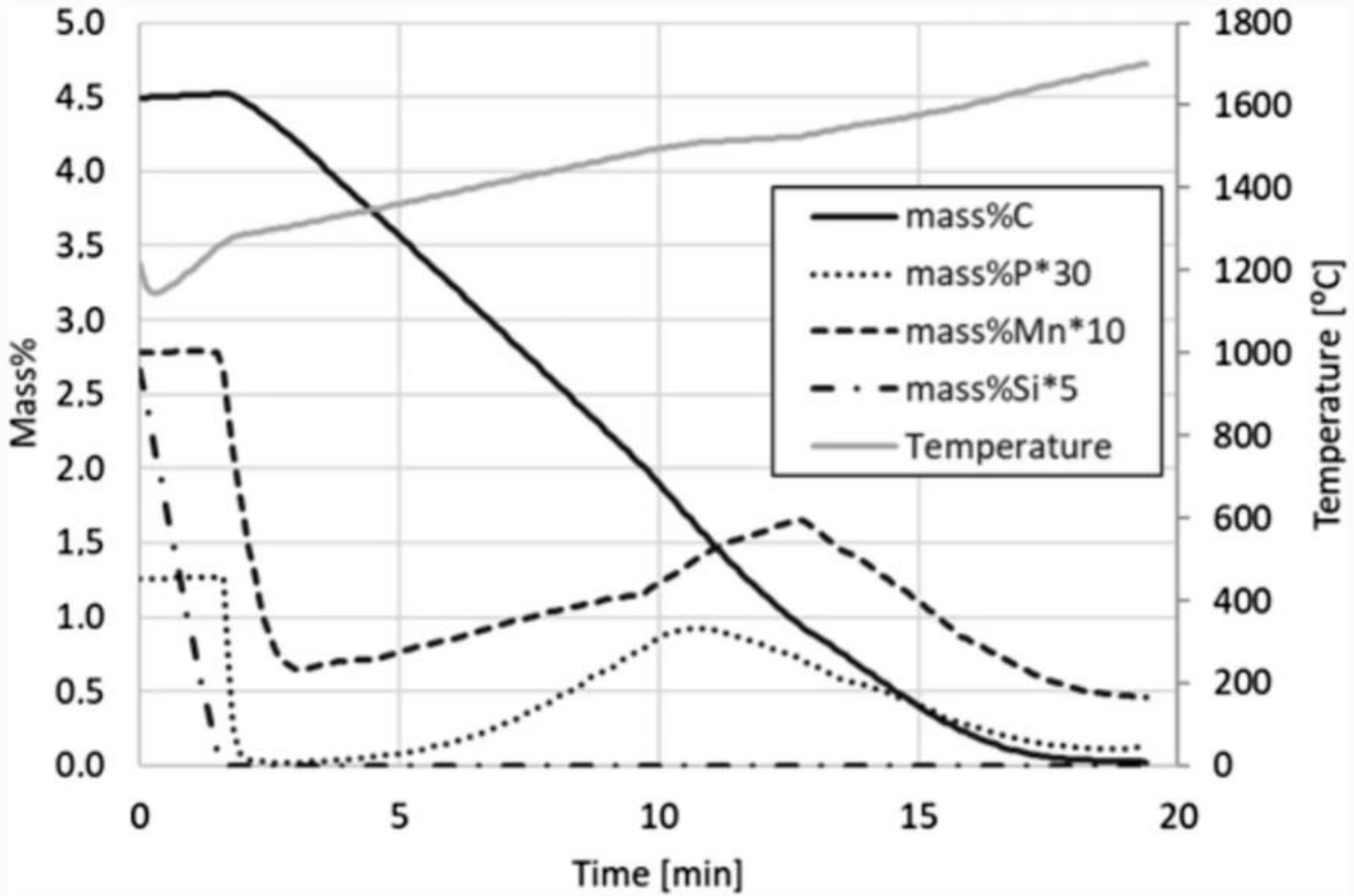
Bulk Material Addition

1. 4000 Kg Lime
2. 4000 Kg Lime + 500 Kg CD
3. 1000 Kg Lime + 500 Kg CD
4. 1000 Kg Lime + 500 Kg CD
5. 500 Kg CD

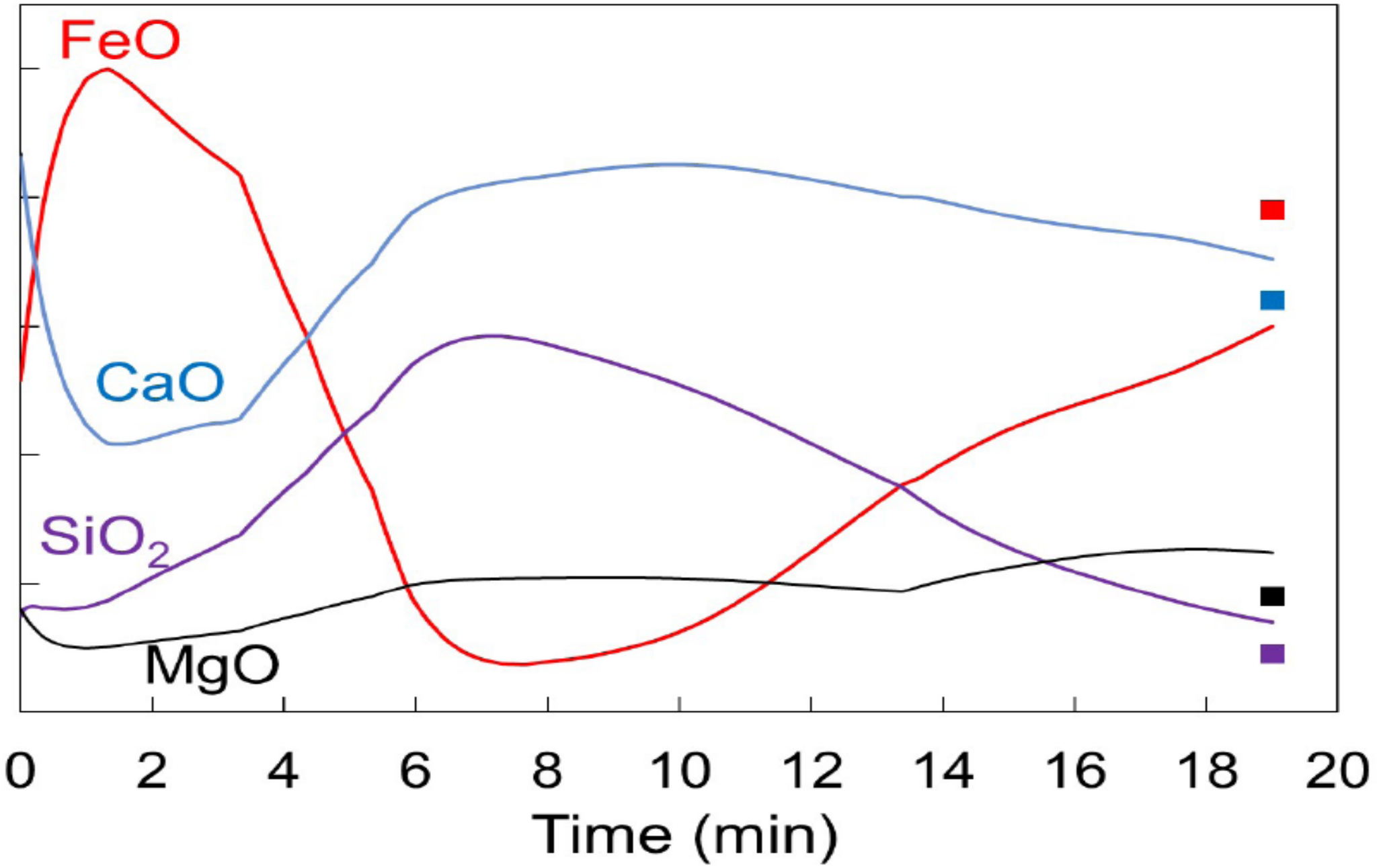
Tap to Tap process at BOF



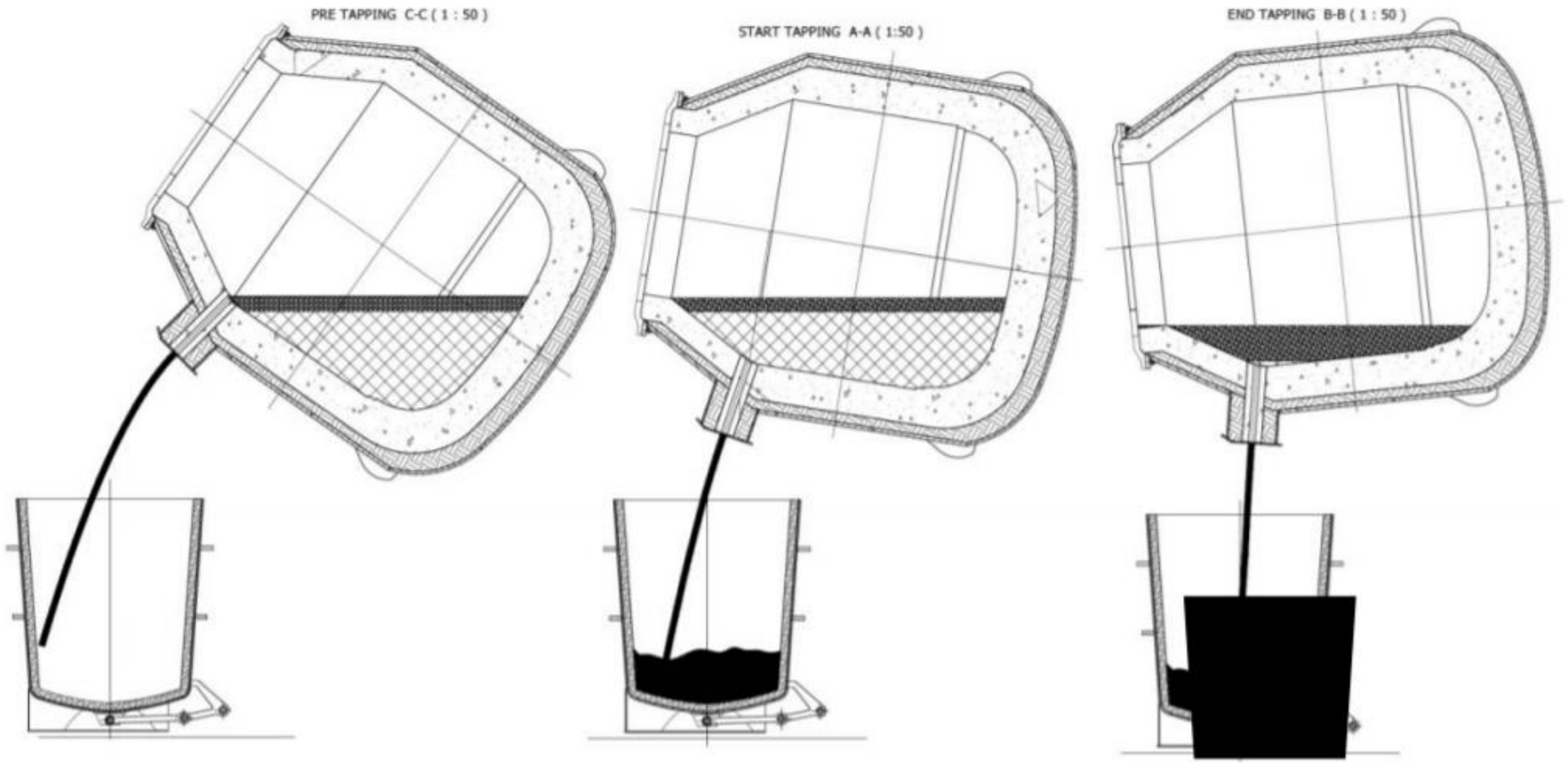
Steel Composition change during reaction



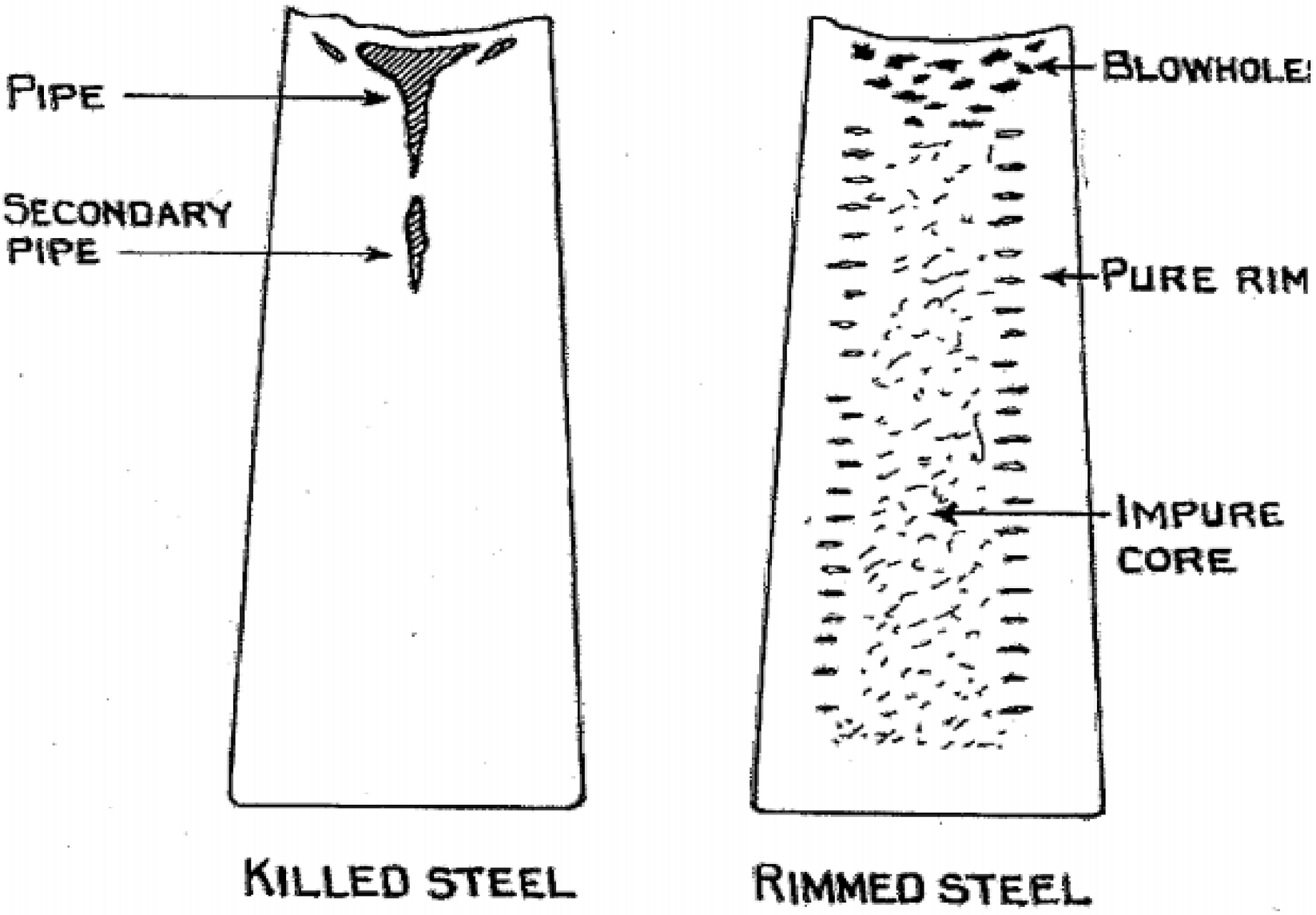
Slag Composition change during reaction



BOF converter tapping



Dissolved Oxygen in Steel



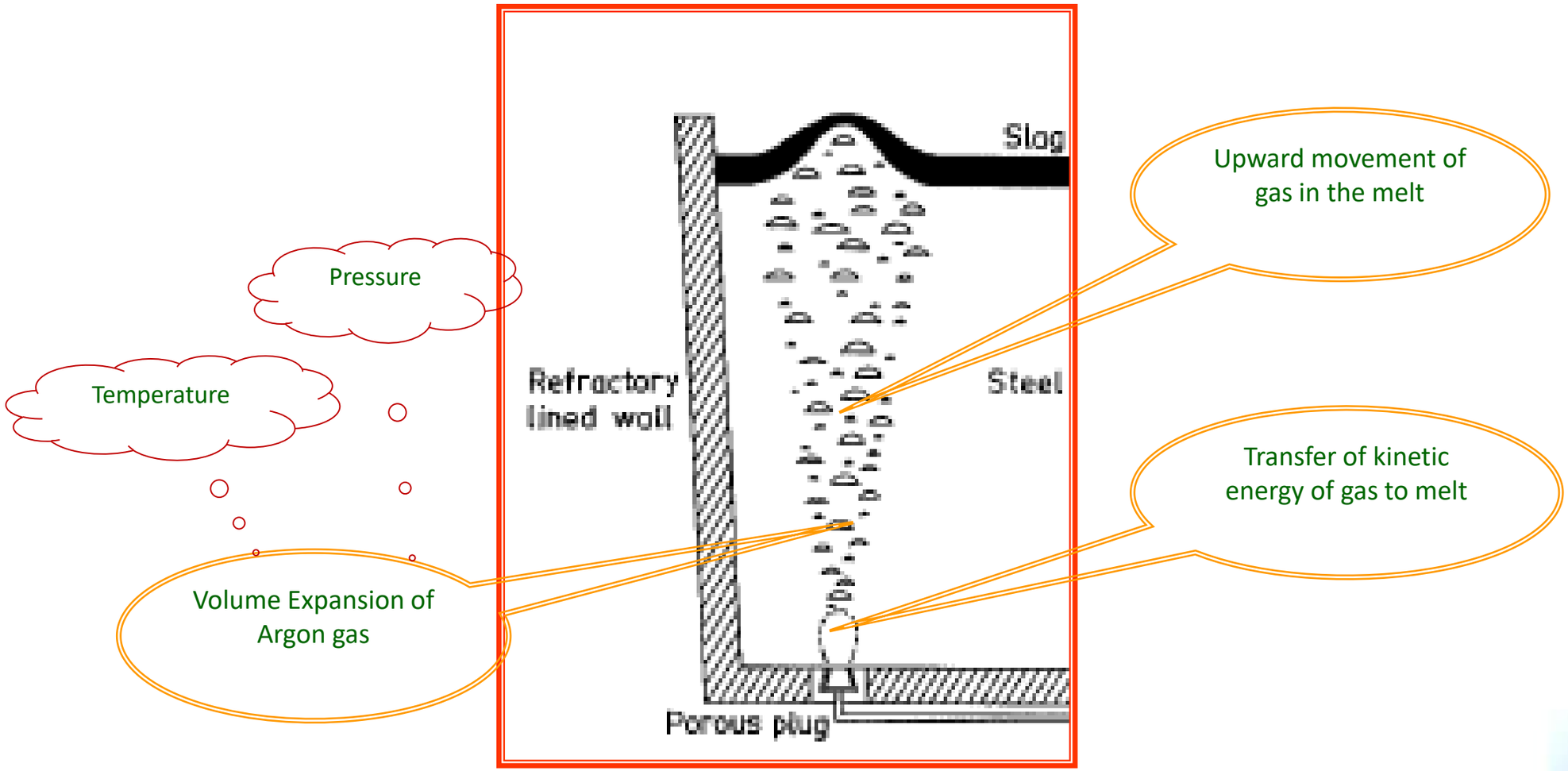
Dissolved oxygen in Steel

BOF end of blowing	• Oxygen 800 to 1200 ppm • Process variable: Reblow/ Overblow
After tapping	• Oxygen ppm 50-100 ppm • Quality & De-oxidising power of Ferro-Alloys
During Casting	• Less than 50 ppm for semi killed steel • Less than 30 ppm for killed steel

Cleanliness requirement of various steel grades

Steel Product	Max Allowed Impurity Fraction	Max Allowed Inclusion Size
IF steels	[C]- 10-30 ppm, [N]≤40 ppm, T.O.≤40 ppm	
Automotive and deep-drawing Sheets	[C]≤30 ppm, [N]≤30 ppm	100μm
HIC resistant steel sour gas tubes	[P]≤50 ppm, [S] ≤10 ppm	
Bearings	T.O.≤10 ppm	15 μm
Wires	[N]≤60 ppm, T.O.≤30 ppm	20 μm
Heavy plate steels	[H]≤2 ppm, [N]=30-40 ppm, T.O.≤20 ppm	13 μm
CRNO	[N]≤30 ppm	
Plates for welding	[H]≤1.5 ppm	

Mixing phenomena in steel ladles

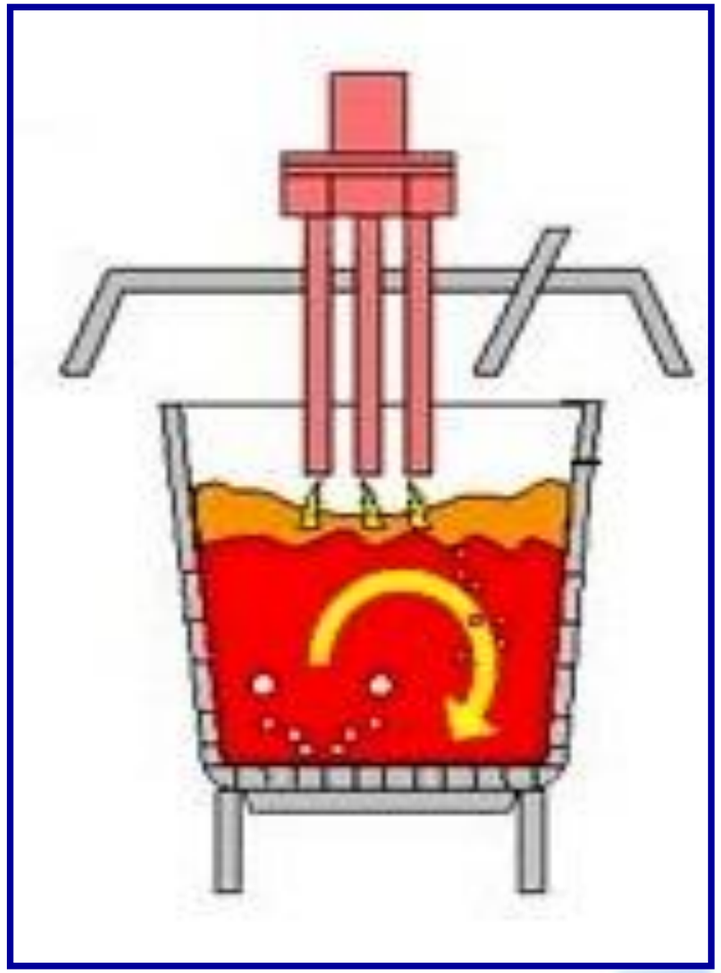


Stirring intensity is mainly controlled by gas flow rate

Secondary refining of steel

Stirring Intensity

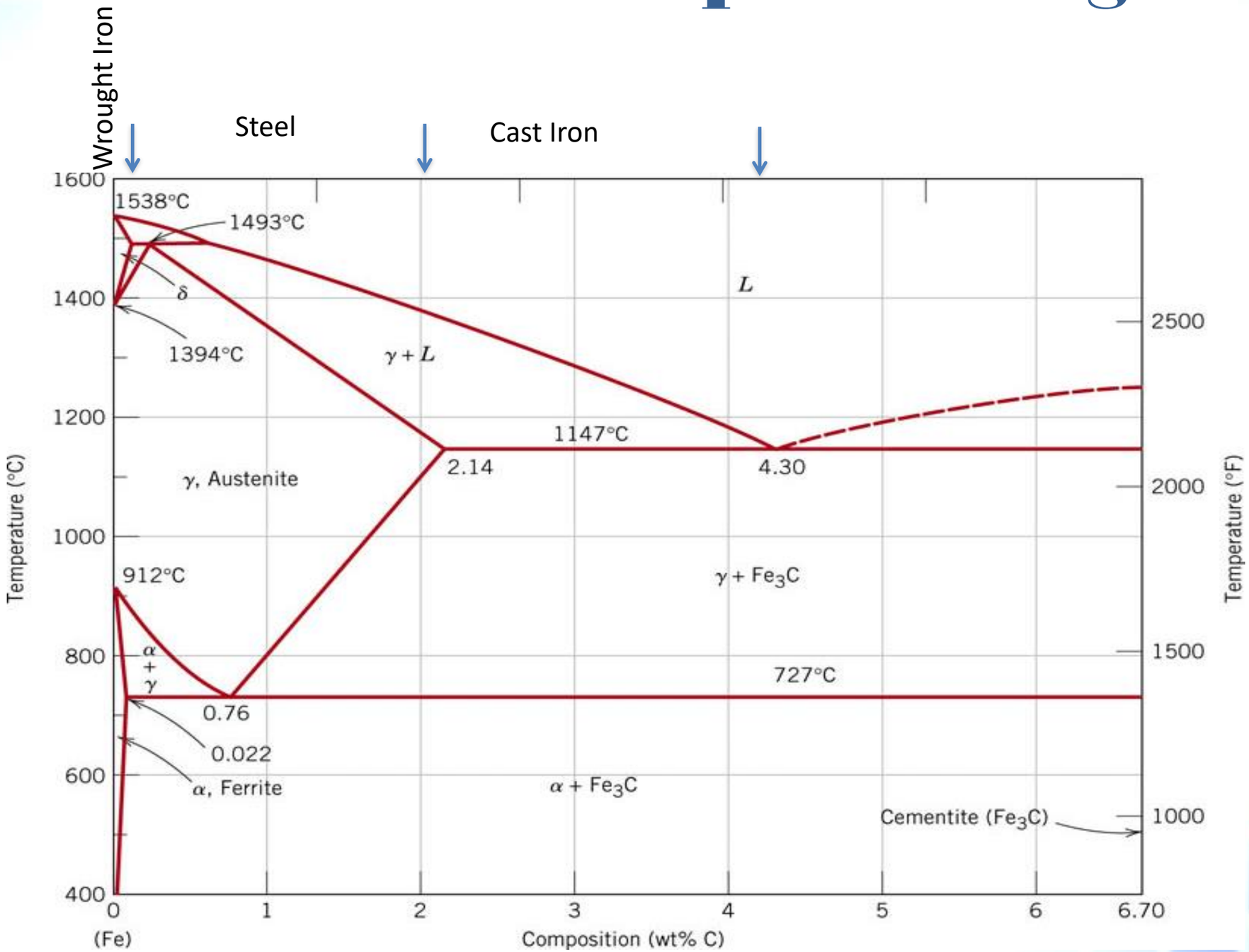
- Efficiency of De-S also depends upon circulation rate of steel.
- Stirring helps in achieving nearly complete mass transfer between metal, slag.
- Intense stirring helps in increasing the kinetics of desulphurisation reaction
- High level of stirring energy can be achieved by higher argon flow rate and high bath temperature.



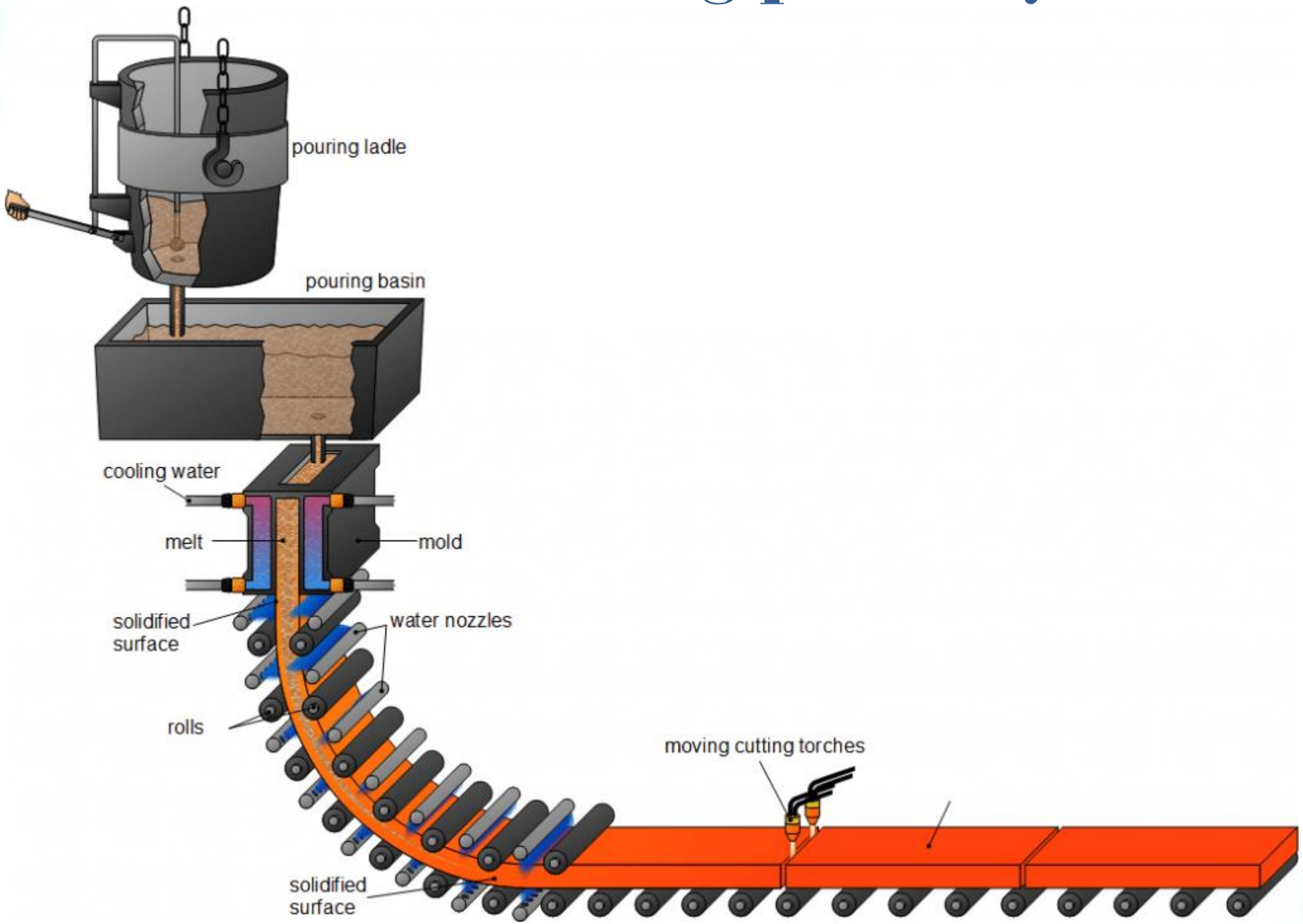
Ladle Furnaces 130T

Ladle Furnace(1 & 2)	Furnace Transformer 25 MVA, Crompton Greaves	130 T	Danieli
Ladle Furnace(3)	Furnace Transformer 25 MVA, ABB	130 T	Eastern Metec
VAD Unit(1 No)	Furnace Transformer 15 MVA, Stem Trento.	120 T	MESSO Metallurgie

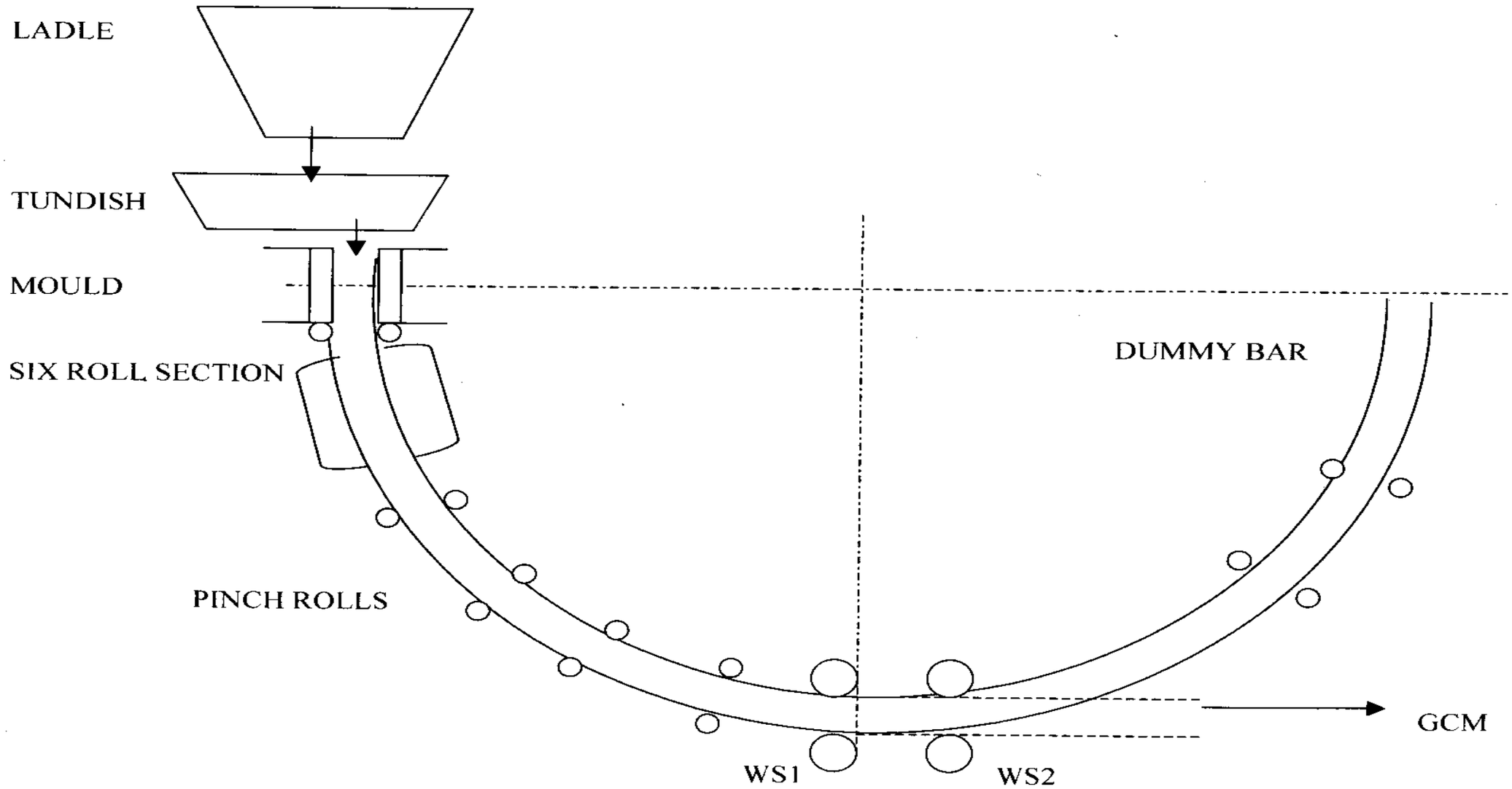
The Iron- Iron Carbide phase diagram



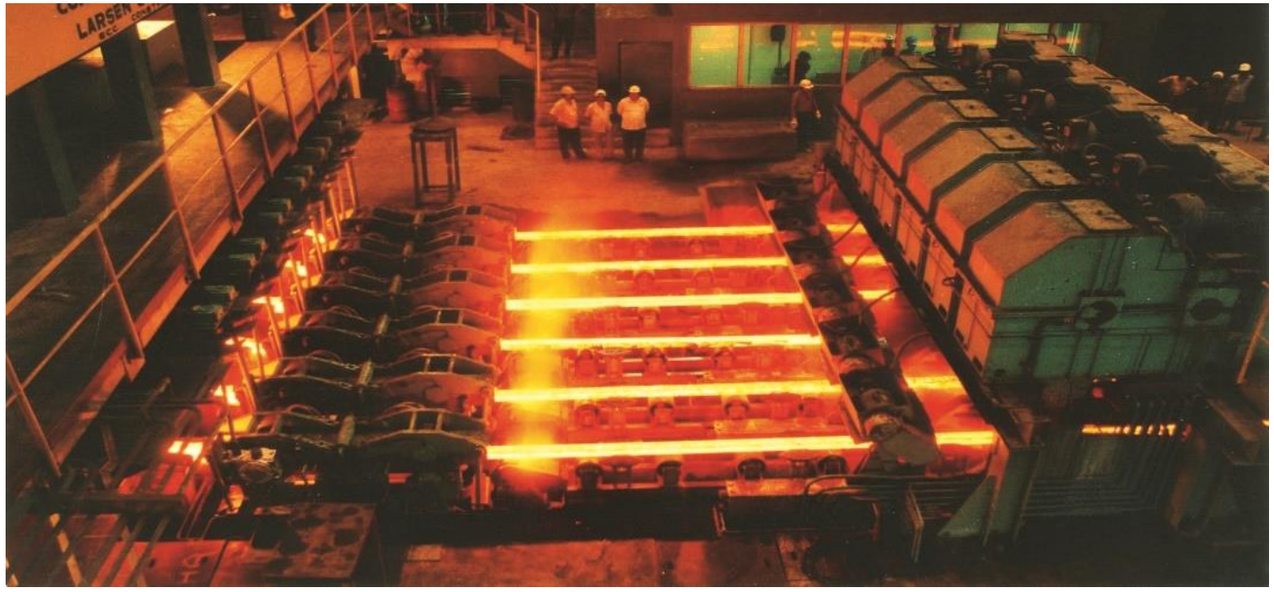
Continuous Casting plant layout



BLOOM CASTING MACHINE

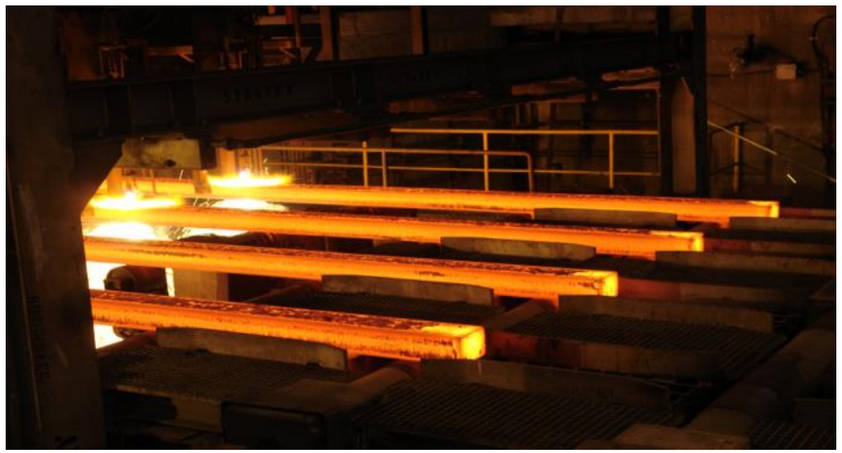


Billet Caster



Year of start up	1994	
Supplier	CONCAST ZURICH	
Type	S 15-6	
Heat size (nominal)	120	t
Caster productivity	95	t/h
Number of strands	6	
Distance among stand axis	1100	
Dummy bar type	FLEXIBLE	

Bloom Caster



Sections : 160/210,160/230,200/200,150/300,150/350

Year of start up	2007	
Supplier	DANIELI	
Heat size (nominal)	120	t
Annual production	7,50,000	tpy
Number of Strands	4	

Bloom cum Round Caster

Sections : 240/350, 150/300, Round

Year of start up	2015	
Supplier	DANIELI Centro Met	
Heat size (nominal)	120	t
Annual production	7,50,000	tpy
Number of Strands	4	

BILLET CASTER SPECIFICATIONS

- Make: Concast standard
- Machine Type: S 15-6
- Number of strands: 6
- Machine Radius: 6 m
- Machine Productivity: 125-140T/hr
- Casting Sections: Machine 1: 100x100 mm2, Machine 2: 125x125 mm2
- Ladle capacity: 130 T (max) [Avg.: 120 T]
- Ladle Support: Ladle turret with lifting system
- Tundish Capacity: 13 T
- Tundish Level Control: Load Cell on Tundish Car
- Tundish Support: Liftable Tundish Car (convertible type)
- Tundish stream Control: plug
- Mould Tube: Multitaper, curved 1000mm long,
- Mould Lubrication: Oil
- Mould Level Control: Radioactive
- Straightening: Modular Type (4 modules/strand)
- Casting speed: 3-3.5 m/min
- Cutting: Mechanical Shear (360 T)
- Dummy Bar: Not Rigid

BLOOM CASTER SPECIFICATIONS

• Make:	Danieli
• Machine Type:	3BLC904
• Number of strands:	4
• Machine Radius:	9 m
• Unbending radius:	16 m
• Machine Productivity:	125-140T/hr
• Metallurgical Length:	25 m
• Casting Sections:	160x210, 160x230, 150x350 (mm^2)
• Ladle capacity:	130 T (max) [Avg.: 120 T]
• Ladle Support:	Ladle turret with lifting system
• Tundish Capacity:	24 T (overflow at 26 T)
• Tundish Level:	800 mm (overflow at 850 mm)
• Tundish Level Control:	Load Cell on Tundish Car
• Tundish Support:	Liftable Tundish Car (cantilever type)
• Tundish stream Control:	Electromechanical Stopper Rod
• Steel Stream Protection:	Submerged Entry Nozzle (SEN)
• Mould Tube:	Multitaper, curved 1000mm long,
• Mould Lubrication:	Casting Powder
• Mould Level Control:	Radioactive
• Electromagnetic Stirring:	Positive for future
• Oscillating unit:	Hydraulic Type
• Straightening:	Modular Type (4 modules/strand)
• Withdrawal speed:	0.6 – 6 m/min
• Cutting:	Oxy cutting torch with sample cutting system
• Cutting Length:	3.4 – 10 m
• Dummy Bar:	Rigid
• Cooling Bed:	28m long, 12m wide

Defects in Continuous Casting

- Cracks
  - Surface cracks
  - Internal cracks
- Segregation
  - Macro segregation (Centre)
  - Micro segregation (Inter-dendritic, Inter-columner)
- Inclusions & Entrapments
  - Indigenous & Exogenous inclusions(D Re-oxidation products, Refractory)
  - Surface Entrapments & Sub-Surface Entrapments (slag, mould powder, refractory etc.)

Quality Issues of Material Origin

- **Manifestation as**
  - **Surface imperfection visible with naked eye or special test**
    - **Crack, Lamination, Sliver**
  - **NDT failure : internal imperfection**
- **Originating from**
  - **Poor cleanliness : exogenous entrapment or endogenous NMI**
    - **Related to refining and casting process**
  - **Surface, subsurface, internal cracks**
    - **Related to specific grade & casting process**

Measures in Ladle to control Entrapments

- ❑ Free opening & slide-gate opening with shroud
- ❑ Ar shrouding to prevent O & N pick-up

Ar	**30 lpm**	**~ 10 ppm N**
Ar	**60 lpm**	**~ 5**
Ar	**100 lpm**	**Nil**

- ❑ **Deep immersion of shroud in tundish**
- ❑ **Detection system to prevent slag carryover**

Or

Enough steel in ladle before change-over

Measures in Tundish

- **Suitable Flow modifier (turbulence inhibitor, argon diffuser etc)**
  - **Improved flow facilitates NMI floatation**

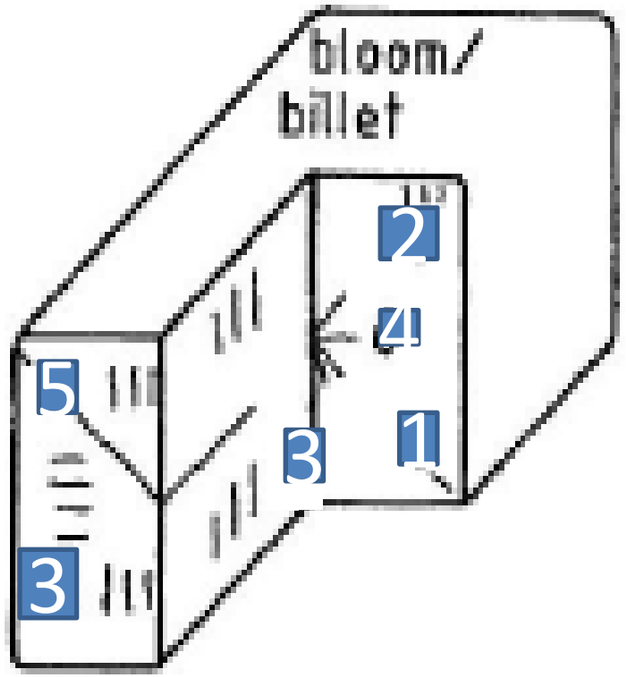
- **Inert lining with better insulation**

- **Tundish stopper with porous plug and Ar**
  - **Prevents contamination with clogged Al_2O_3**

Measures in Mould

- **Control of mould level fluctuation**
  - Prevents slag / powder entrapment
- **Avoiding sudden change in casting speed**
  - Prevents slag / powder entrapment
- **Argon shrouding to prevent nozzle clogging**

TYPES OF INTERNAL DEFECTS



1. Longitudinal corner cracks.
2. Longitudinal off corner cracks.
3. Halfway cracks.
4. Spider cracks.
5. Diagonal cracks

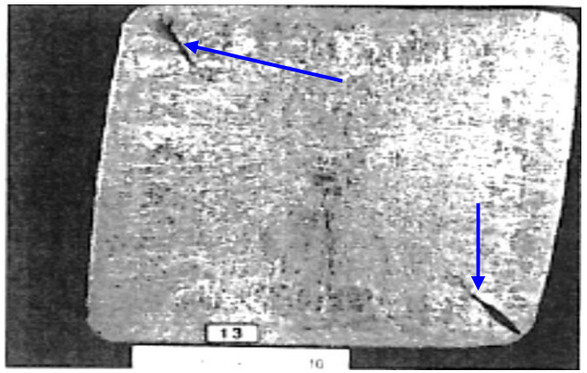
Defects in CC products:

Rhombodity

CHARACTERISTICS

- Difference between length of two diagonals > 10 mm
- More pronounced in steel grades with C from 0.15 to 0.30%
- May lead to breakout in extreme cases

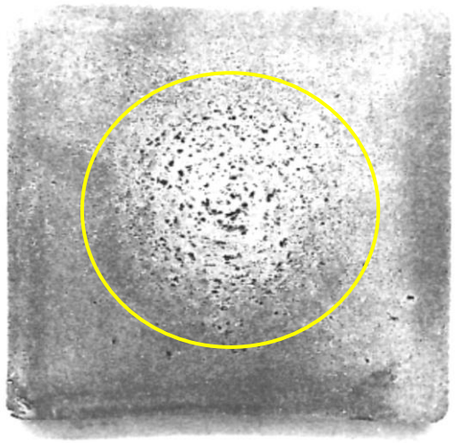
1. LONGITUDINAL CORNER CRACKS ASSOCIATED WITH RHOMBODITY – BILLETS & BLOOMS ..

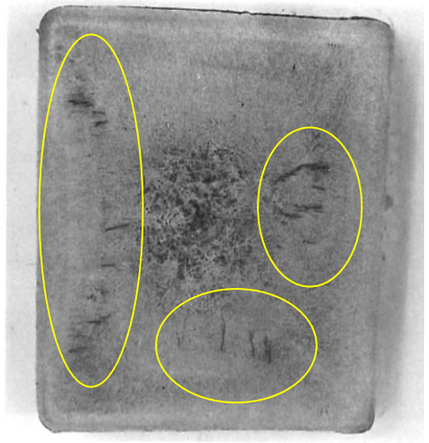


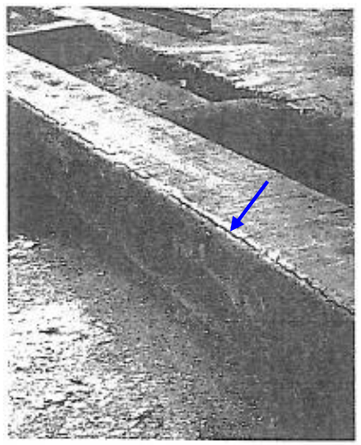
REMEDIAL MEASURES

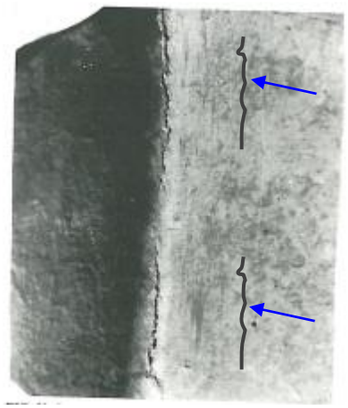
- Correct alignment of liquid stream into mould.
- Check mould tube alignment.
- Replace mould.
- Identical nozzle parameters such as water flow, spray angle and height of all nozzles on each side of the billet.
- Check for clogged nozzles.
- Check nozzle performance.

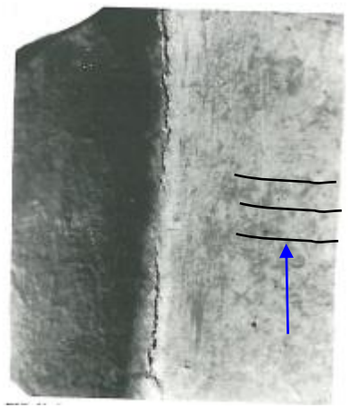
Various types of defects in steel billets



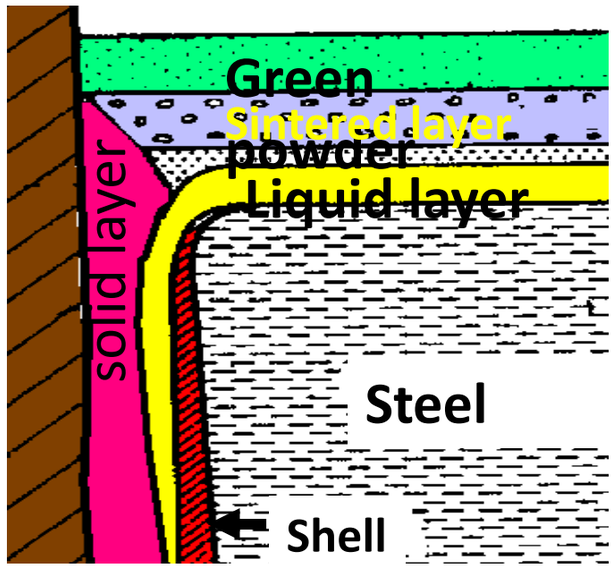








Shell formation in Continuous casting mould



η = Viscosity
V_m = Mould velocity
V_c = Casting Speed
dl = Liquid slag layer
η_s = Coeff. of solid friction
H = Ferro-static force

Powder slag film between strand and mould contribute:

- **Liquid Friction :** Dominates just below meniscus

$$f_l = \eta \times (V_m - V_c) / dl$$

- **Solid Friction:** Acts in lower part of mould

$$f_s = \eta_s \times H$$

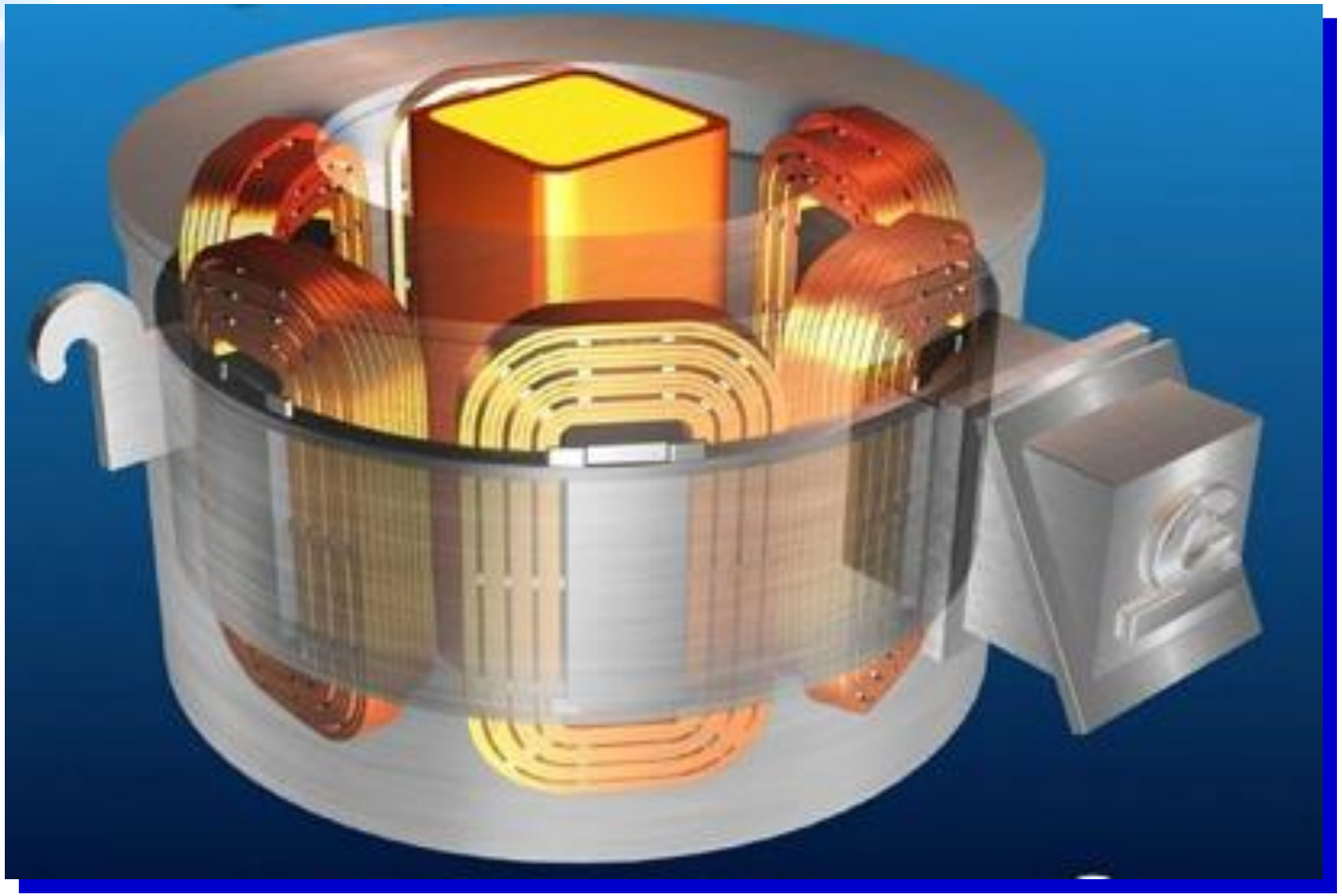
Problems associated with weak shell

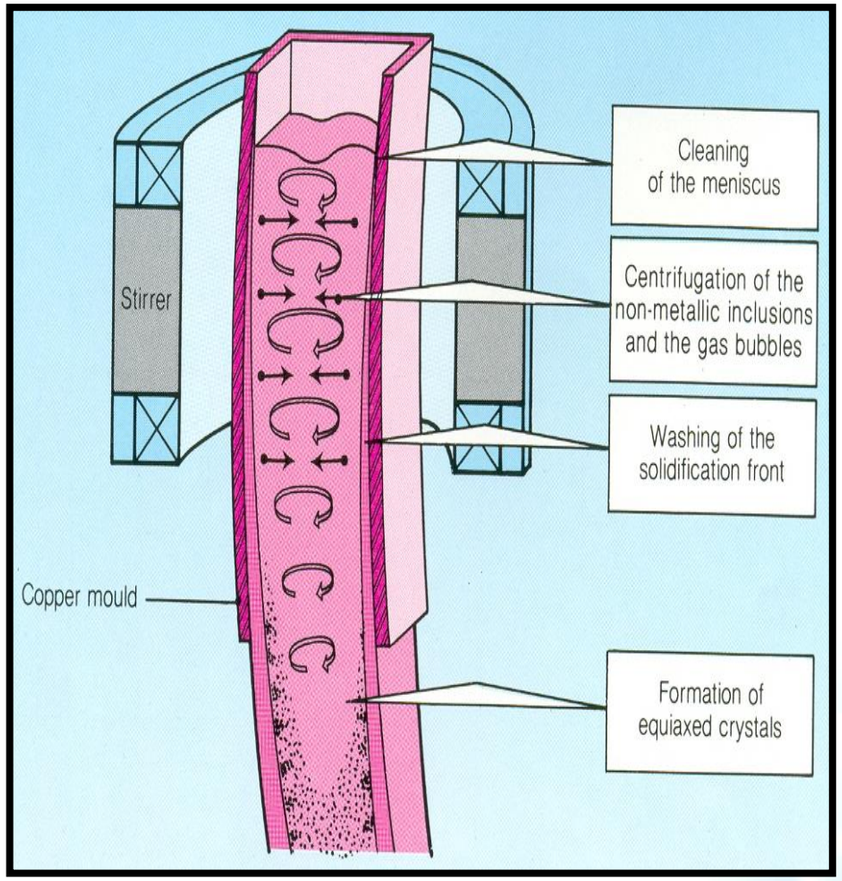
Multiple punctures in solidified steel shell, the size of punctures in this strand is larger as comparted to strand-02

Caster break out & metal splashing in cooling zones

Metal splash found in the mobile sector, just below the mould, in all 4 sides.

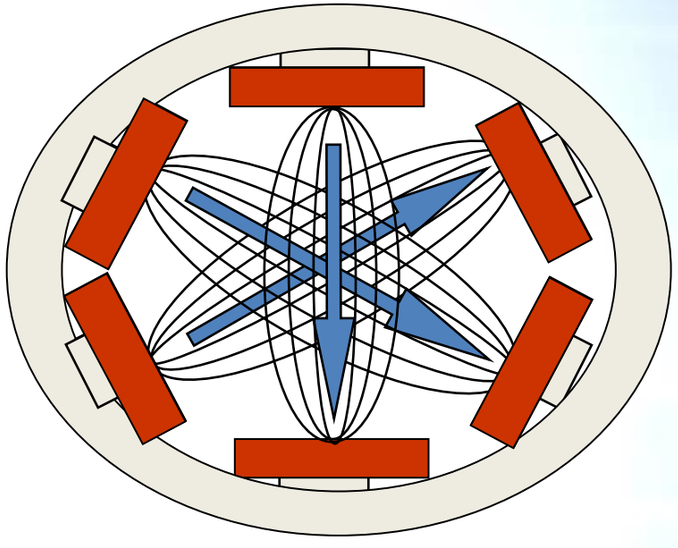
Mould EMS in Continuous casting



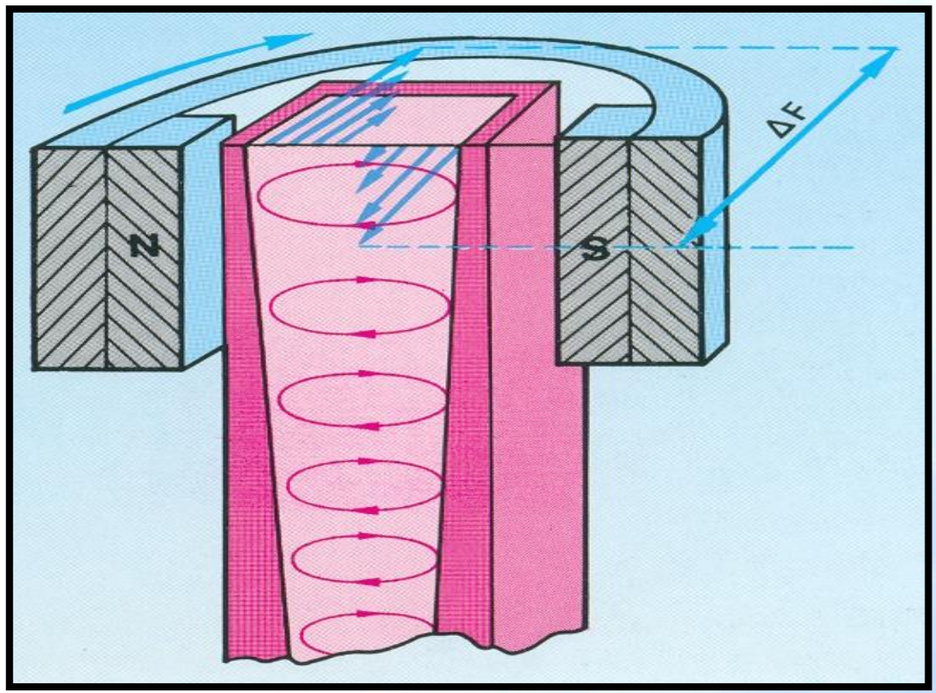


Principle of liquid steel stirring

Rotative stirrer



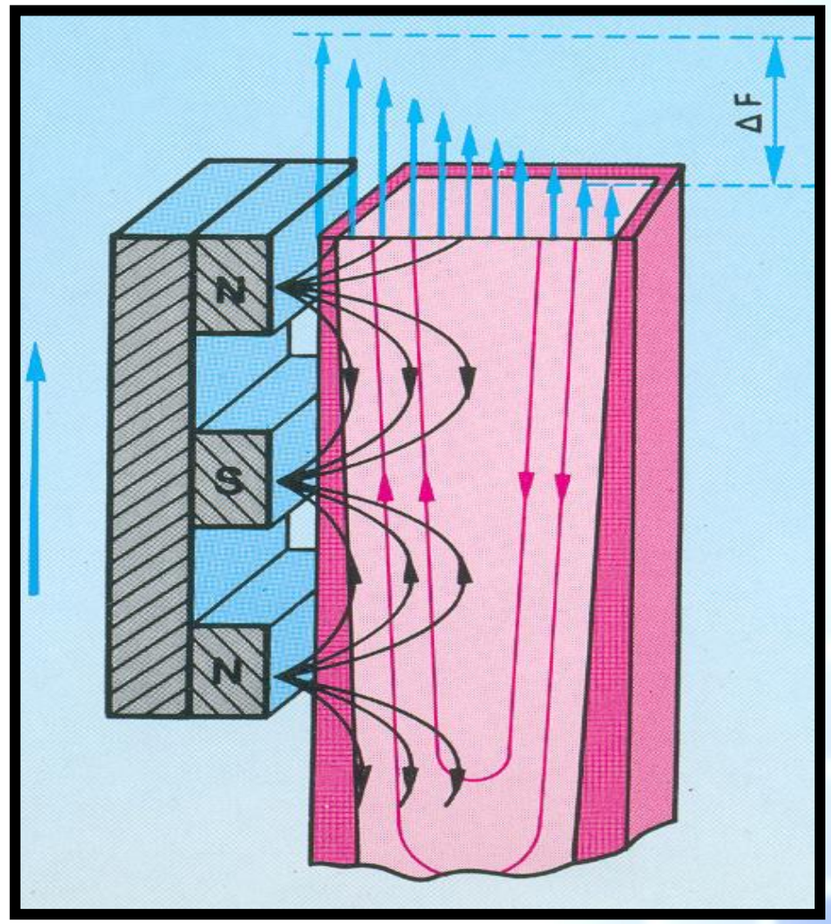
- Rotative stirrer acts like the stator of an asynchronous AC motor and the liquid steel represents the rotor
- Three phase/two phase power supply creates a rotating magnetic field within its pole gap.
- Rotating magnetic field induces a torque in the liquid steel passing through the stirrer
- Liquid steel, under the influence of this force, acts as the rotor of an AC motor and rotates around the axis of the cast product



Principle of liquid steel stirring

Linear Stirrer

- Stator creates a travelling magnetic field
- This magnetic field induces a force inside liquid steel pointing towards the travelling direction
- Stirred zone confined to the length of stirrer

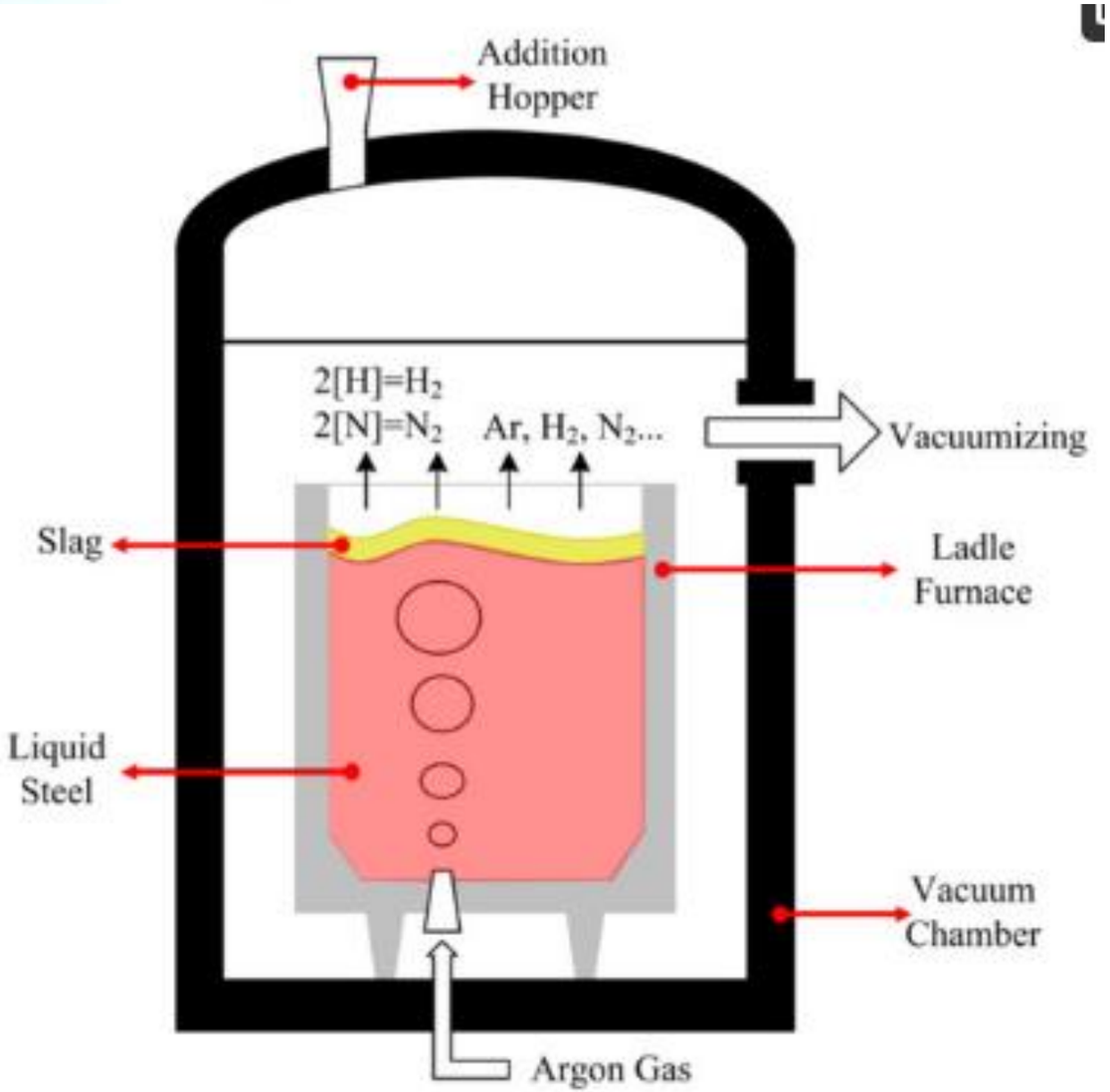


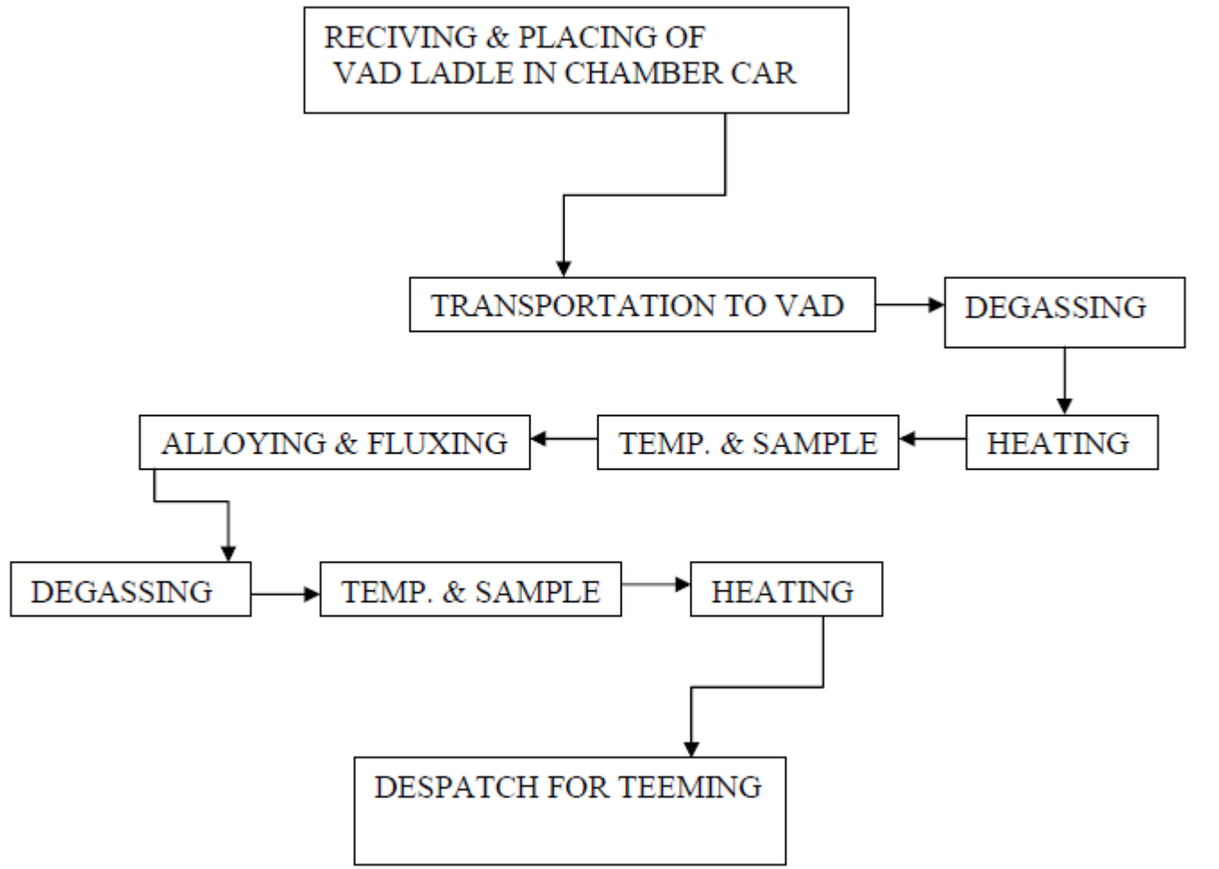
Rotational stirring superior in terms of fluid dynamics & metallurgical improvement

Steel quality improvement due to Mould EMS in Continuous casting

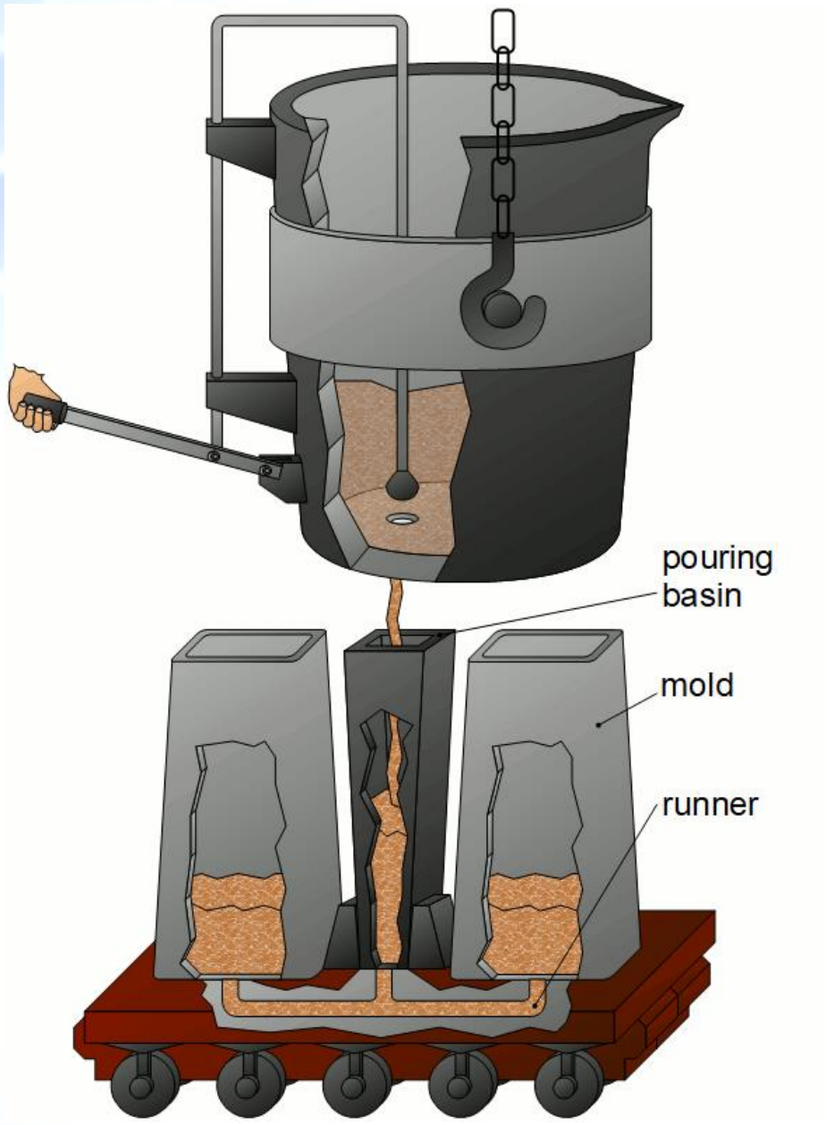
- Internal Quality improved by reduced segregation
- Larger equiaxed solidification structure
- Improved subsurface and internal cleanliness by a modified metal flow pattern
- Parameters for casting widened (w.r.t. Temperature & Speed)

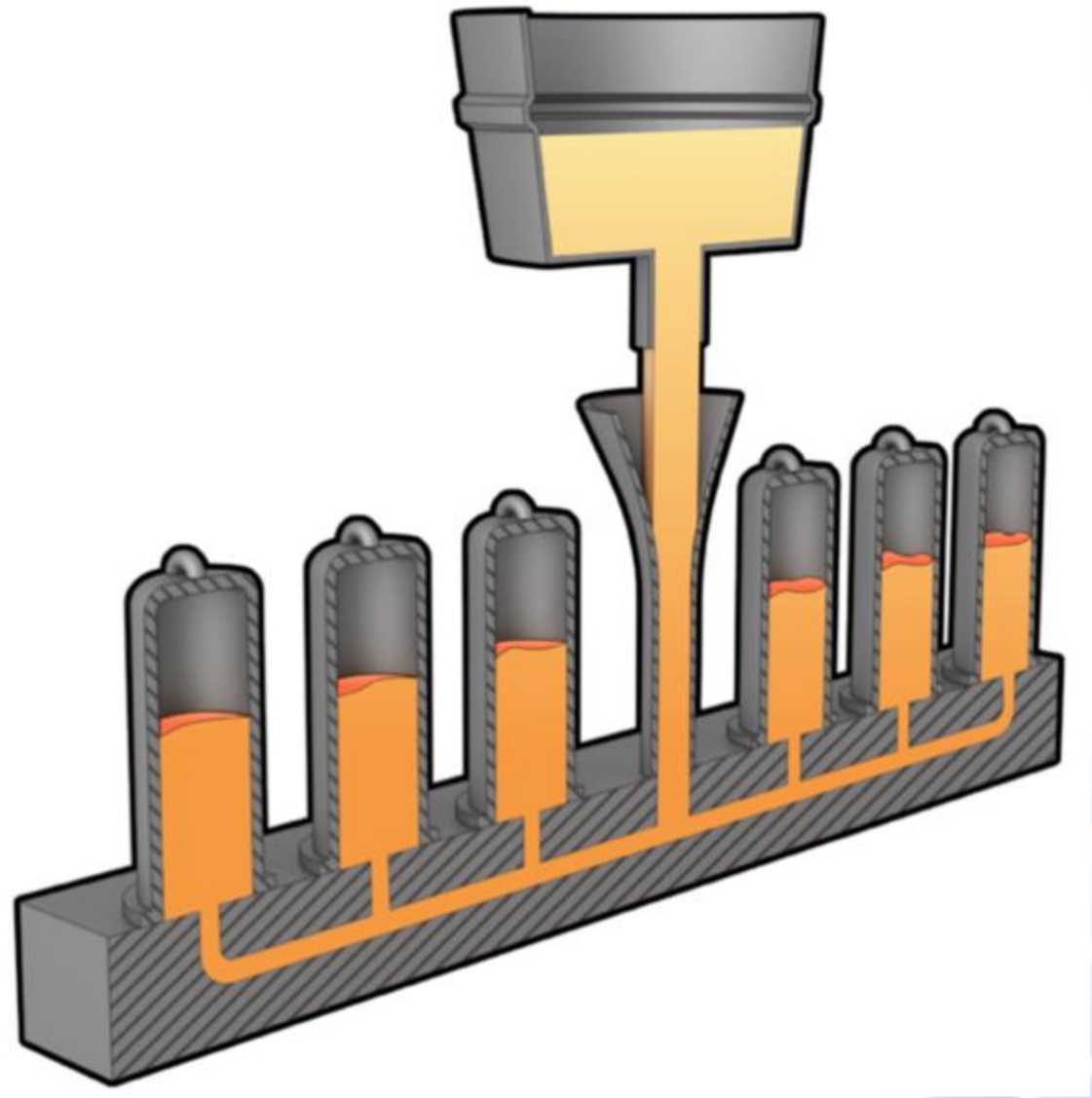
VAD process for wheel steel





Process of casting wheel steel



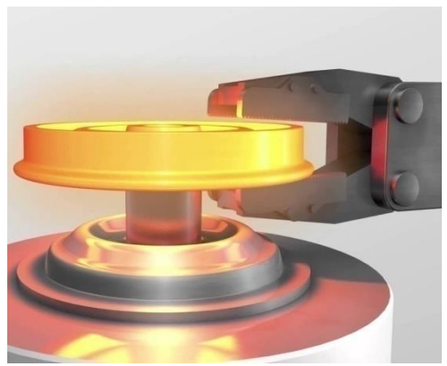


Wheel steel making process

Finish

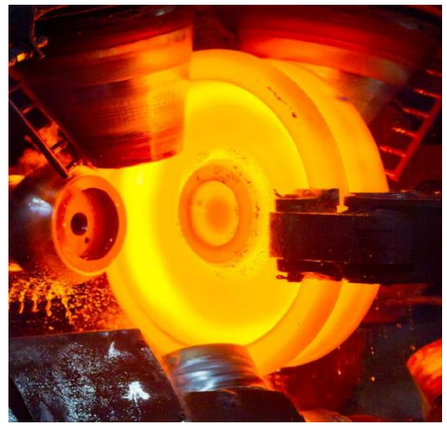
#5

Rejected wheel at UT stage



Finished wheel

#4



Wheel forging & rolling

#3

Block cutting

#2

Molten steel casting

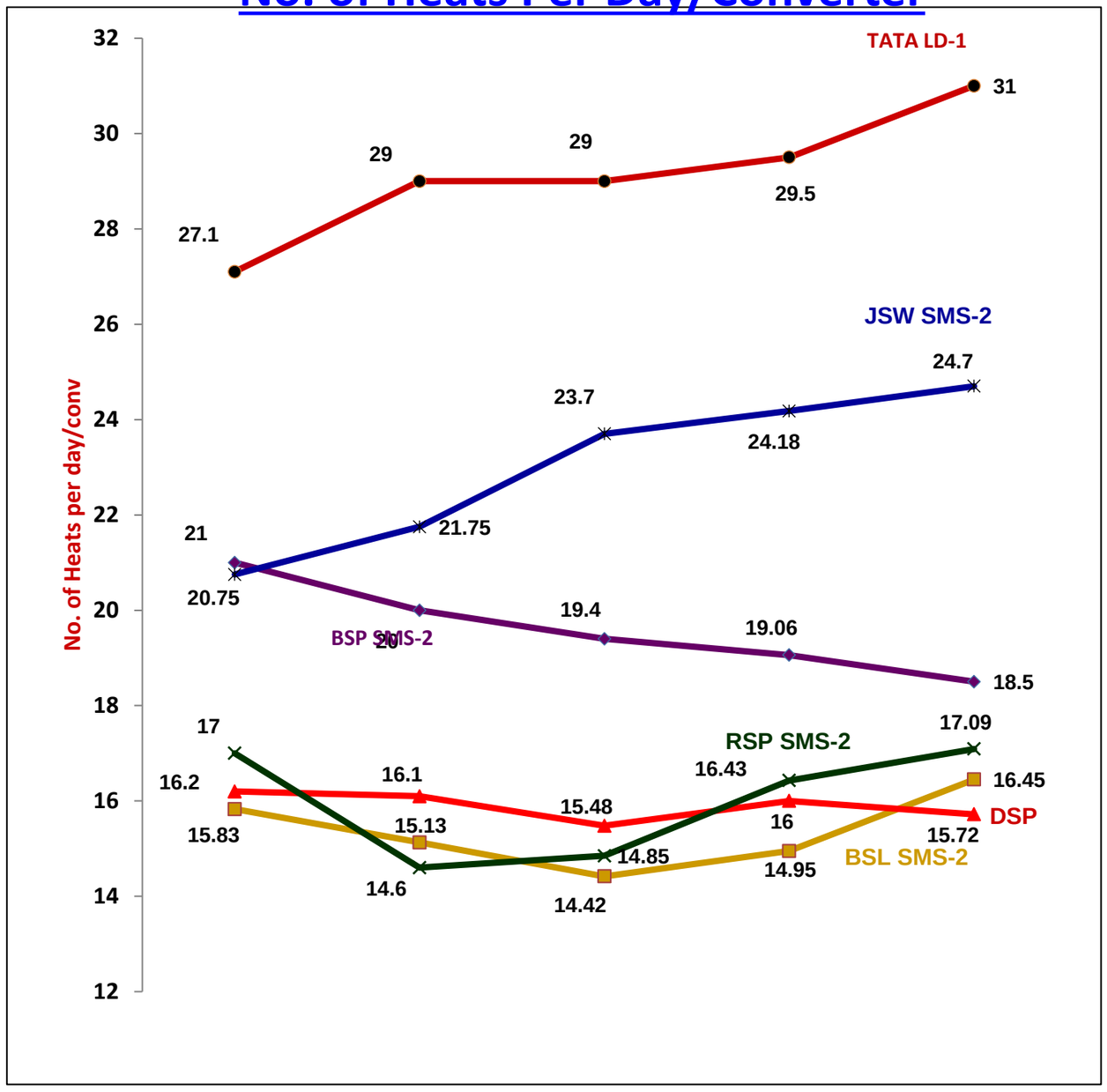
#1

Start

हर एक काम देश के नाम

Overview of Last Five Year Performance

No. of Heats Per Day/Converter



Steel Making Operating Parameters : 2019-20

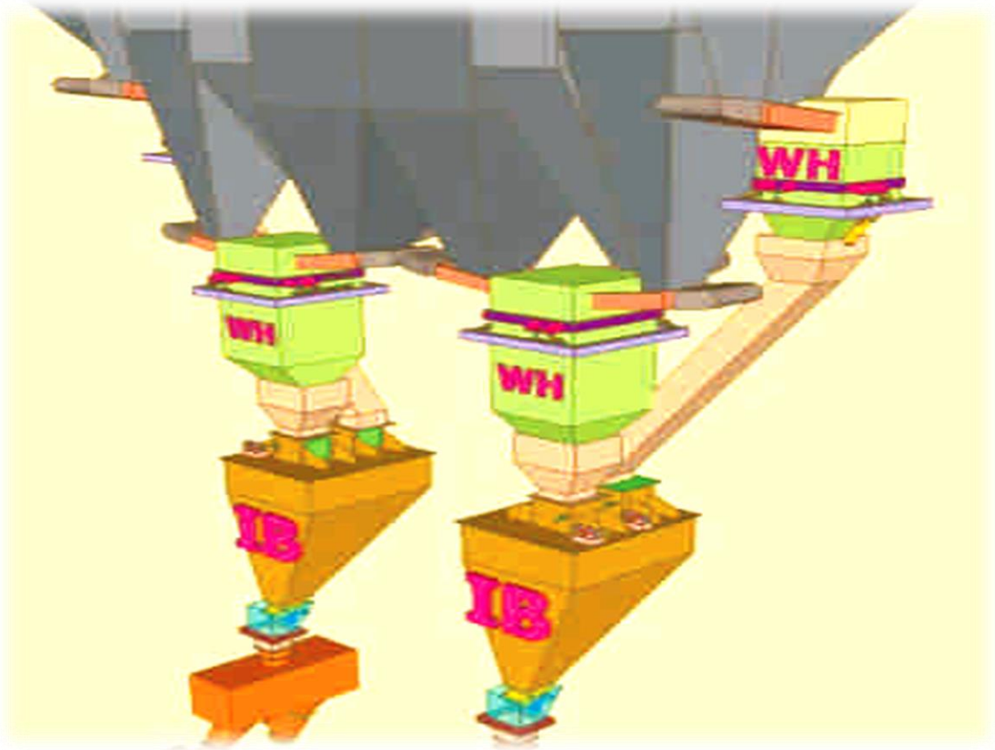
Parameters	BSP SMS-II	BSL SMS-II	DSP	RSP SMS-II	ISP	TATA Steel LD – 1	JSW SMS -2
BOF Lining Life (avg)	9578	3682.5	6104	6336	3066	5490#	4385#
Avg. BOF Tapping Temp (°C)	1650	1671	1671	1685	1684	1661	1662
Tap to Tap Time (min)	55	56	53	59	80	40	57
BOF Converter Yield (%)	86.30	88.40	91.02	89.64	91.78	-	-
Sp. Oxygen Consp. (Nm^3/tcs)	62.86	56.02	54.10	50.30	53.42	47.80	50.52
Converter Utilization (%)	78.10	78.22	85.98	89.91	64.17	-	-

Best figures are underlined

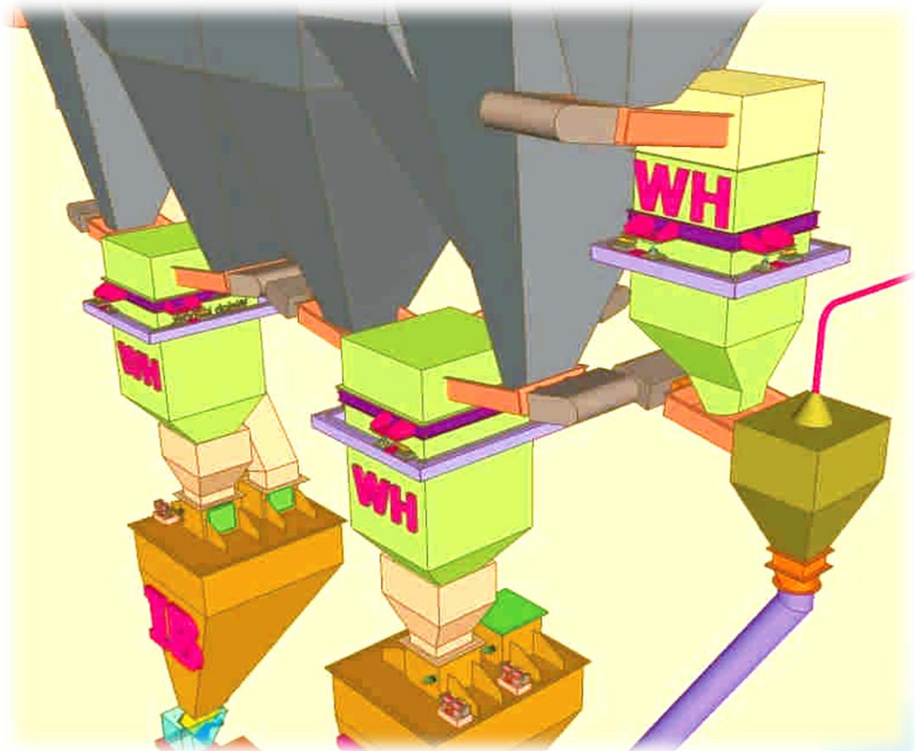
100% Combined blowing

Continuous Iron ore charging in BOF

Original design



Modified design



Rolling of TMT bars from 125*125 concast billets

In-house modification- 25% increase in productivity of billet caster

Billet caster

18T Tundish facility

QNC introduced

Modification in cooling circuits

Merchant Mill

Installation additional cooling pipe

Installation of additional stands

Modification of guides & roll passes

हर एक काम देश के नाम

BOF converter shell changing project during Covid-19 times

Scheduled time: 55 Days

Converter-2, during Nov-2020

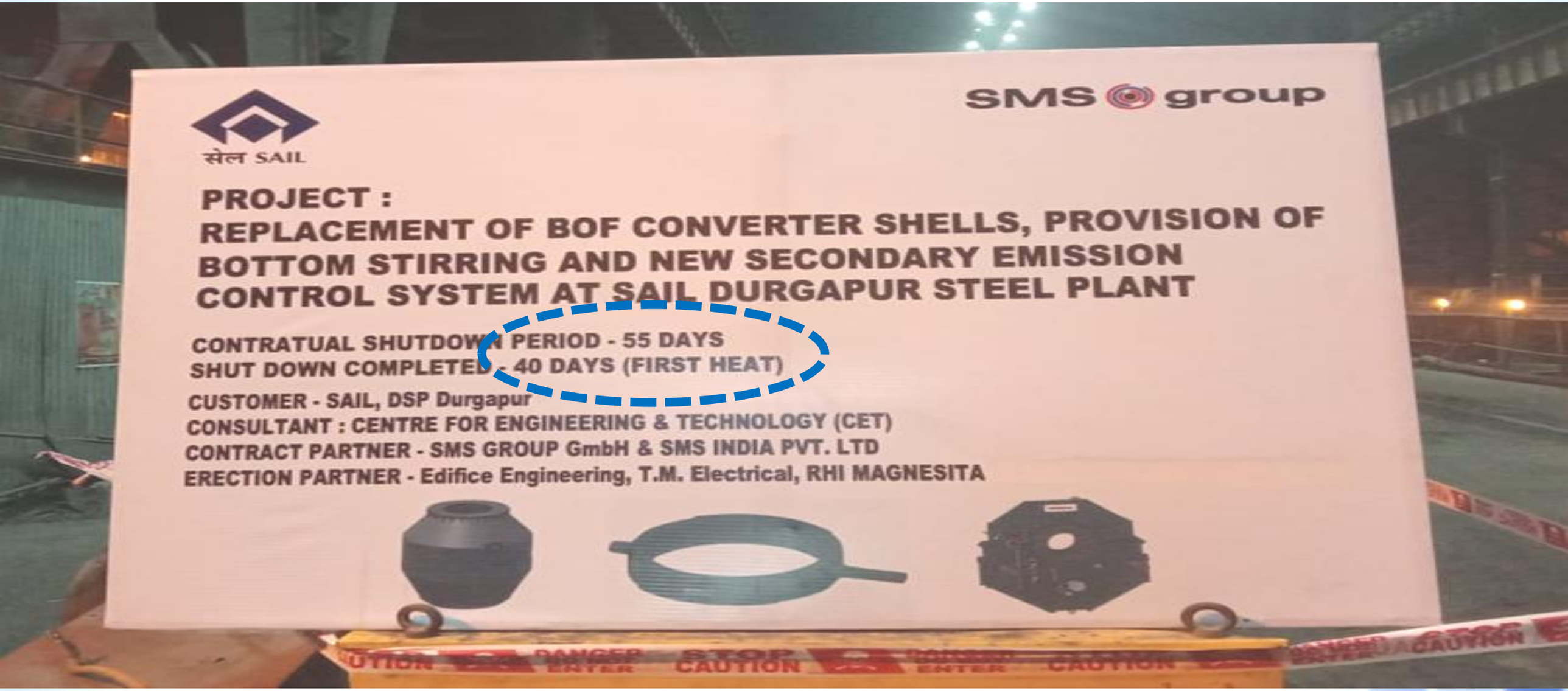
55 Days

Converter-3, during June-2021

40 Days

हर एक काम देश के नाम

BOF converter shell changing project during Covid-19 times



हर एक काम देश के नाम

DSP & ASP collaboration

350*240 blooms from BRC of DSP

From DSP to ASP

Hot Rolling at ASP

Φ 90 -125

100/110 RCS

From ASP to Customer

End Application

हर एक काम देश के नाम

Durgapur Steel Plant

THANK YOU