Steelmaking

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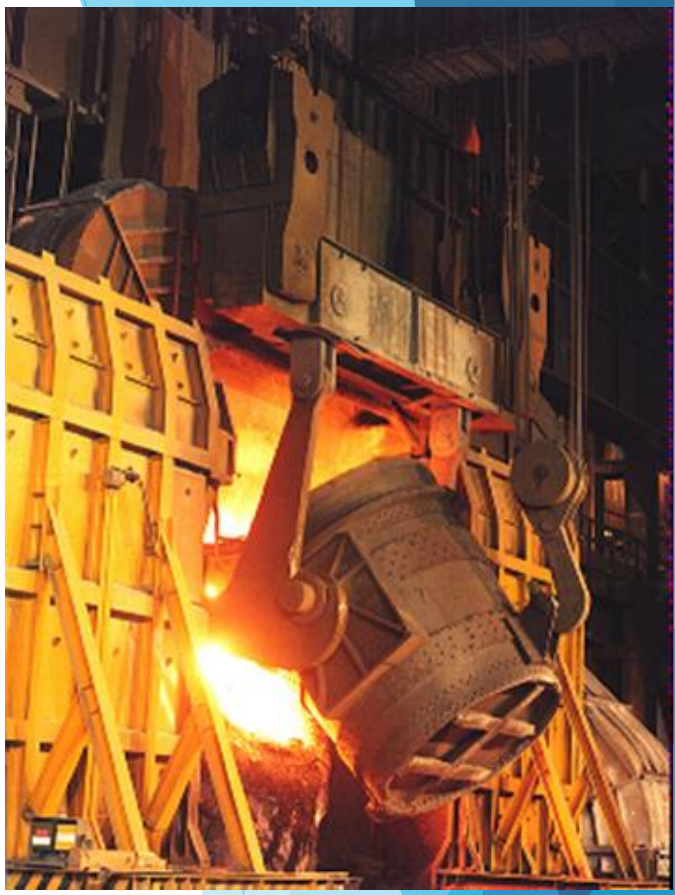
Basic Oxygen Steelmaking (BOS)

60% of the world's total output of crude steel

The process



- Replacement for open hearth steelmaking 2 BOS =12 OHF
- Predates concast
- Six storey building needed for long lance
- Top-blowing, bottom blowing or both
- BOS is autogenous or self sufficient in energy unlike EAF
- Raw materials: 70-80% liquid hot metal from blast furnace and steel scrap
- Oxygen (>99.5%pure)
- Product: molten steel 1650°C goes to continuous caster to be solidified into blooms, billets, slabs
- Tap-tap ~40mins, with 50% blowing time

Basic Oxygen Steelmaking

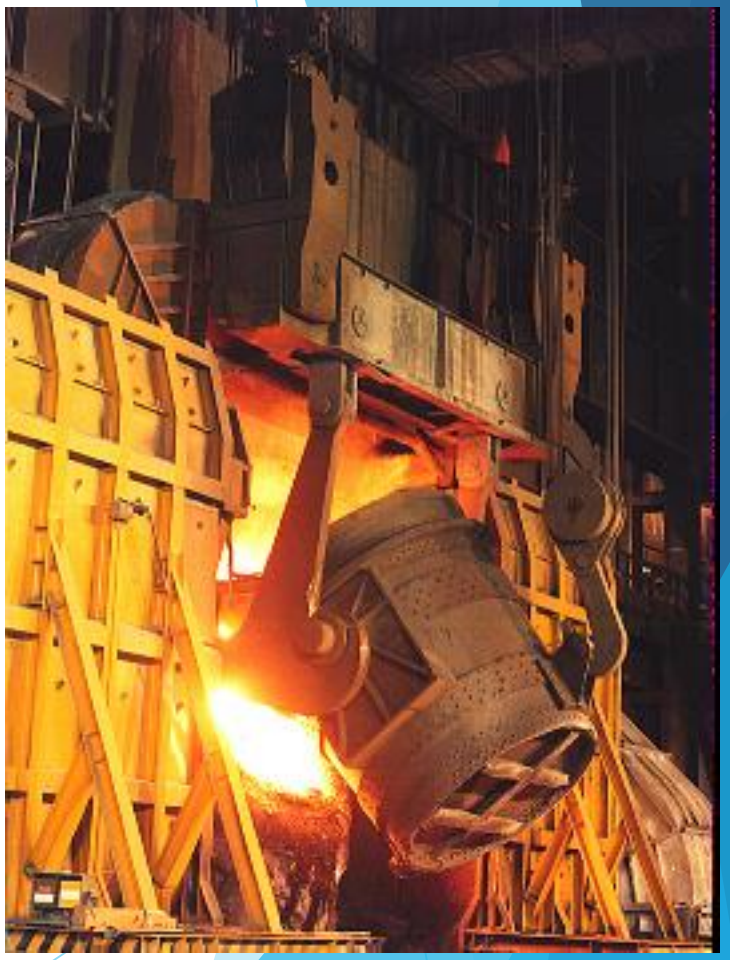
- Blowing oxygen through molten pig iron lowers the carbon content of the alloy and changes it into low-carbon steel. The process is known as basic because fluxes of burnt lime or dolomite, which are chemical bases, are added to promote the removal of impurities and protect the lining of the converter.
- Filling the furnace with ingredients is called ‘charging’
- The charge needs to be balanced- the right ratio of hot metal to cold scrap maintained.
- Vessel tilted 45 degrees
- Scrap charged first from charging box
- Hot metal charged straight after onto scrap from ladle
- Fumes emitted and collected by pollution control system
- Charging takes a couple of minutes
- Vessel rotated back

- The vessel is then put upright
- Water cooled lance lowered to few feet above bottom of vessel to add the oxygen
- Sampling lance also lowered to measure temperature and oxygen levels
- If oxygen purity too low, nitrogen at tap becomes unacceptable
- The oxygen ignites the carbon forming CO and CO_2
- The temperature rises to 1700°C melting the scrap and removing impurities
- Silicon is oxidized forming silica (SiO_2)
- lime /dolomite fluxes are added which react with SiO_2 and form gassy (mostly CO from C in metal) molten 'slag' and envelops lance
- Large amount of gas comes off and slag spills over, black graphite flakes from C in metal
- Blowing continues until sample from sub-lance is analysed and charge chemistry is correct for melt specification (15-20mins) (temperature carbon check)
- Lance moves to different heights during blowing – computer controlled

Basic Oxygen Steelmaking

Scrap being charged into the BOS (left)

A ladle of hot metal(right)



- The vessel is tilted and the steel poured off into ‘torpedos’
- Taphole is blocked with material that prevents the slag entering the ladle as vessel turned down.
- Steel burns through plug immediately
- Slag in torpedo causes phosphor, sulphur
- The vessel is tipped right up so the slag falls out

Torpedo

42
www.alamy.com - F3W930

43
43
gettyimages
Christopher Furlong
143049743

Healy (1973) estimation of Phosphorous distribution

- Using known thermodynamic data
- Log $\frac{[\%P \text{ in slag}]}{[\%P \text{ in metal}]}$ =22350/T -16 +2.5 log%FeT +0.08 x %CaO
  - [%P in metal]
  - Where %P is P content in weight percent

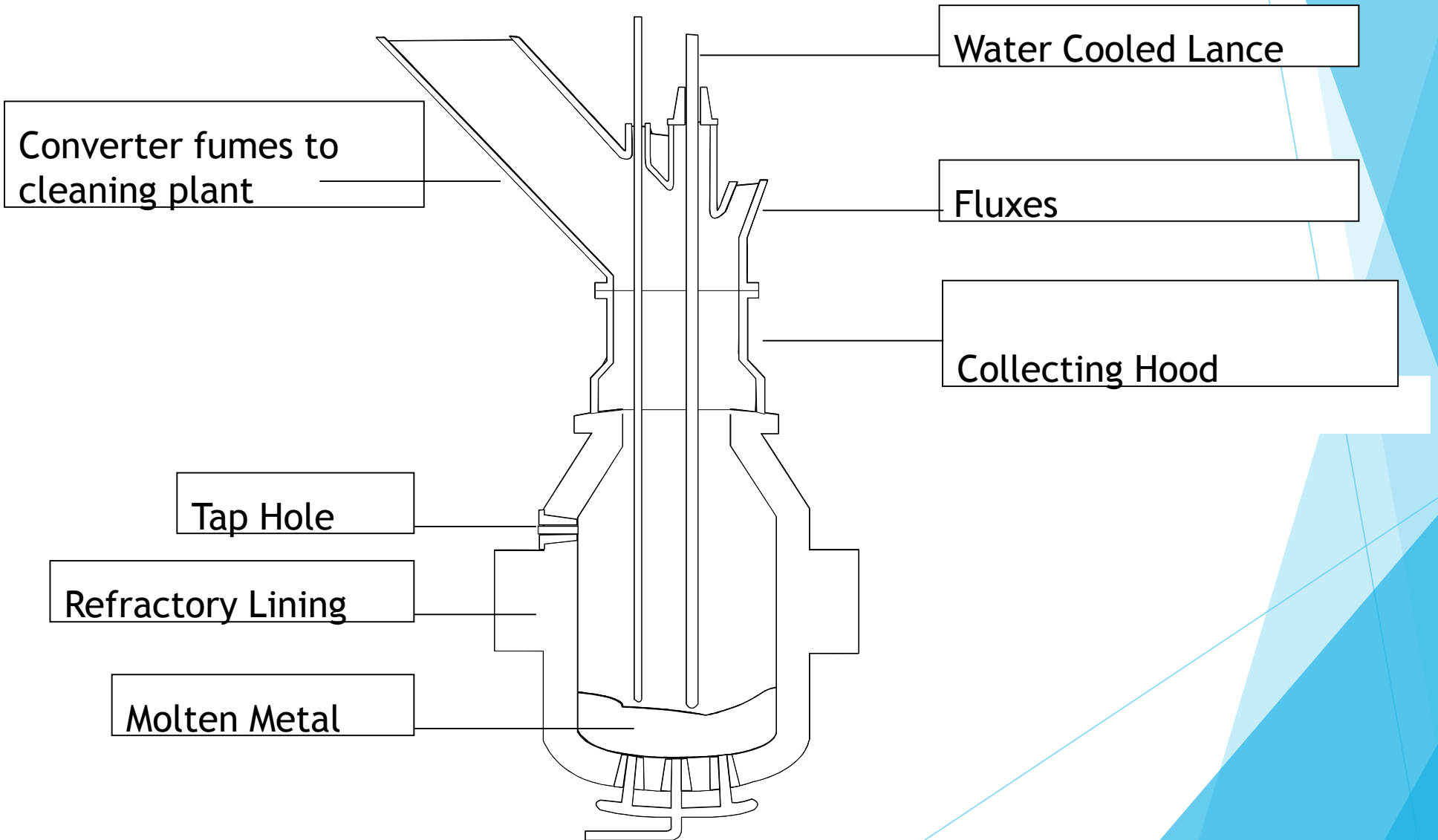
Derge and Tenenbaum 1953 Slag metal chemistry and phosphorous reactions
Phosphorous combines with oxygen and the oxide reacts with lime. Can only happen under basic oxidizing conditions
Manganese and silicon similarly. These reactions exothermic
Control of nitrogen and hydrogen levels affect quality

Bessemer cf EAF

- The basic electric arc furnace is expensive to operate, has a relatively low production rate, and usually results in a product containing relatively large amounts of nitrogen because of the action of the electric arc.

- In the conventional basic Bessemer process the iron charge must contain more than about 1.5% phosphorus in order to provide sufficient heat for the process
- in most instances the iron charged must have a phosphorus content not greater than about 0.4% in order to make all types of steel
- phosphorus cannot be effectively removed until substantially all of the carbon has been eliminated. Limit on low P, high C steel
- consistent elimination of sulfur to low levels difficult

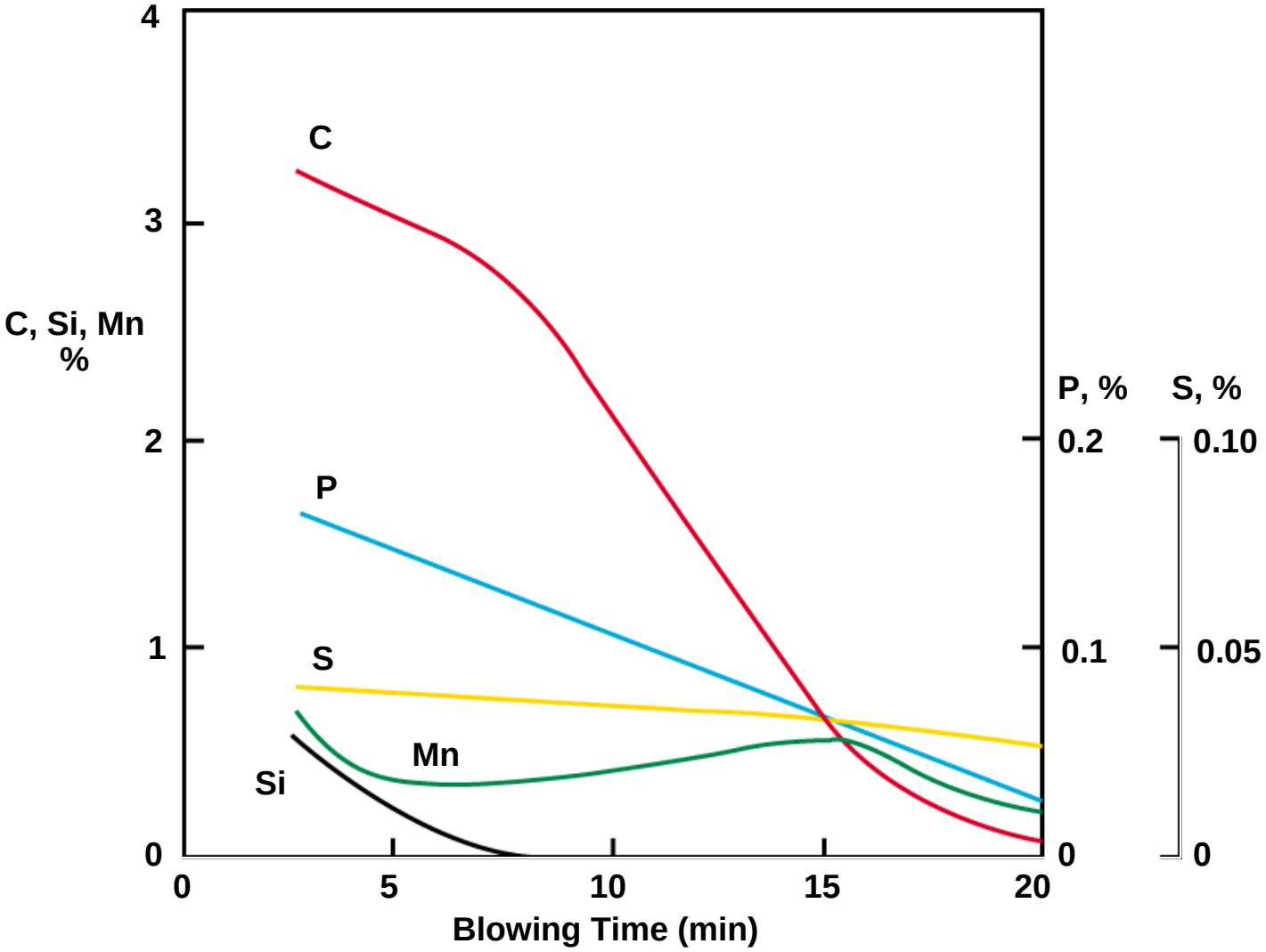
BOS Vessel


Water Cooled Lance
Converter fumes to cleaning plant
Fluxes
Collecting Hood
Tap Hole
Refractory Lining
Molten Metal

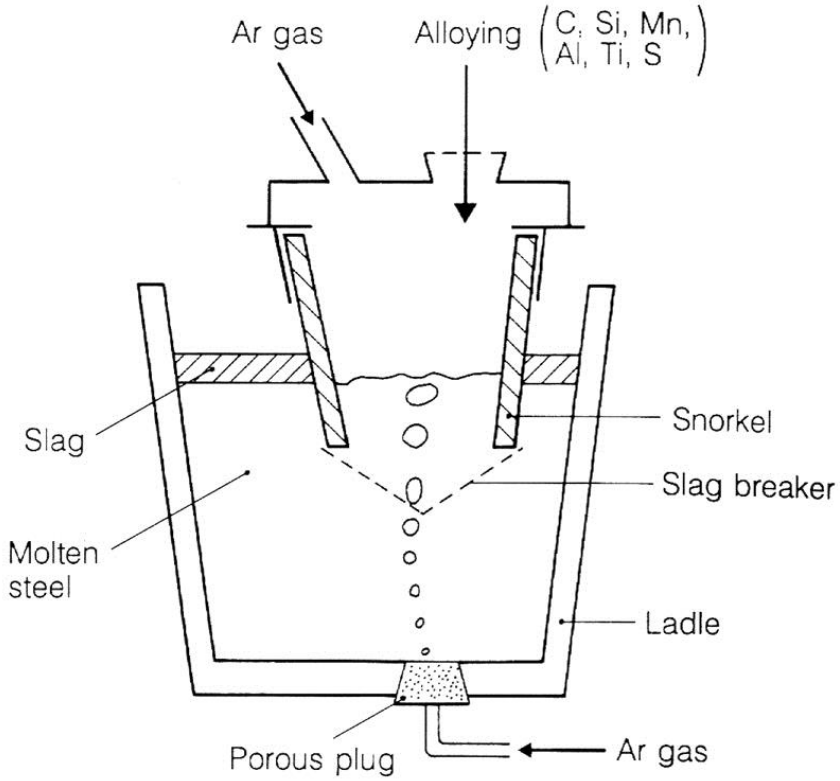
Basic Oxygen Steelmaking

- 2 charging vessels at Port Talbot
- Molten Iron 'charged' into the same vessel
- The mix consists of 20% scrap and 80% molten new iron
- The vessel is 'charged', rotated and oxygen is blown through a water cooled lance
- Oxygen is blown from a height of 2 to 3 metres at a rate of 1000metres/per minute
- The temperature will be raised to 1650°C
- Between 70 to 80 tonnes of steel scrap is 'charged' followed by 300 tonnes of molten iron and 20 tonnes of lime and fluxes

Changes in Metal Composition During The Blow in a Basic Oxygen Steelmaking Converter (idealised)

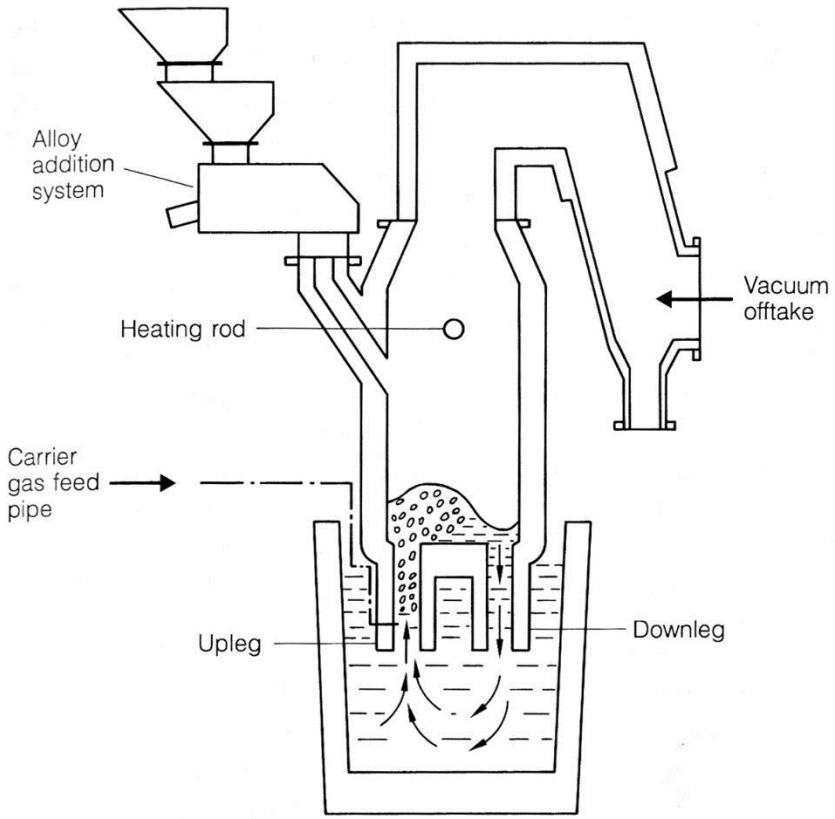


Composition Adjusted Steelmaking CAS- OB



- Used for steels that don't require Carbon removal. This requires a vacuum degasser
- Argon atmosphere in "Bell"
- Excellent alloy recovery by adding alloys through an argon atmosphere
- More predictable chemistry control.
- Argon "bubbling" through bottom of ladle ensures homogeneity of steel.
- Oxygen Blowing (OB) allows reheating and temperature control

RH-OB Degassing



- Used to produce ultra low Carbon Steels for high ductility, continuous processed products e.g CAP, Galvanneal for automotive. e.g. <0.003%C
- Re-circulate steel through a vacuum chamber, the low pressure causes Carbon and Oxygen to react, removing both C and O.
- Since a vacuum atmosphere then alloy recovery is excellent, with no de-oxidation.
- OB stands for Oxygen Blowing. This is a back-up for Reheating to get optimum temperature control to Caster
- Effective for control of nitrogen and hydrogen levels in steel. Other degasser types are more appropriate for some non-strip applications
- Ruhrstahl heraeus

Casting

Solidification

- Metals and alloys

Liquid Steel

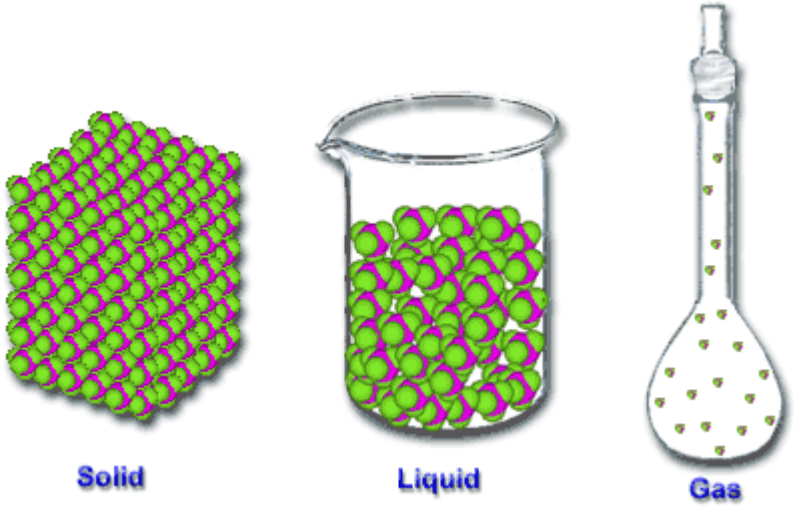
~ 1650°C

- C 0.03 - 0.06wt%
- N 0.002 - 0.005wt%
- Mn 0.15 - 0.3wt%
- Si <0.01wt%
- S, P <0.01wt%
- Al 0.03 - 0.07wt%

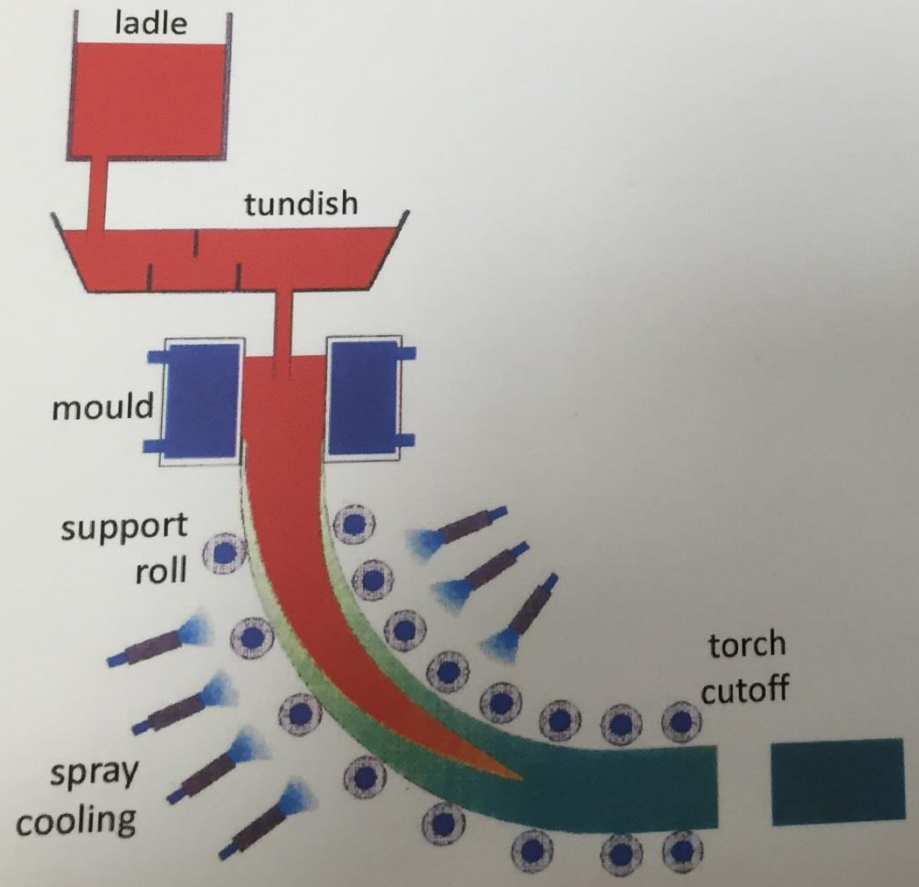
- BOS (Basic Oxygen System) Vessels up to 330T/cast, up to 40min
- Statistical Process Control facilitates a high success rate in achieving a tight specification in composition

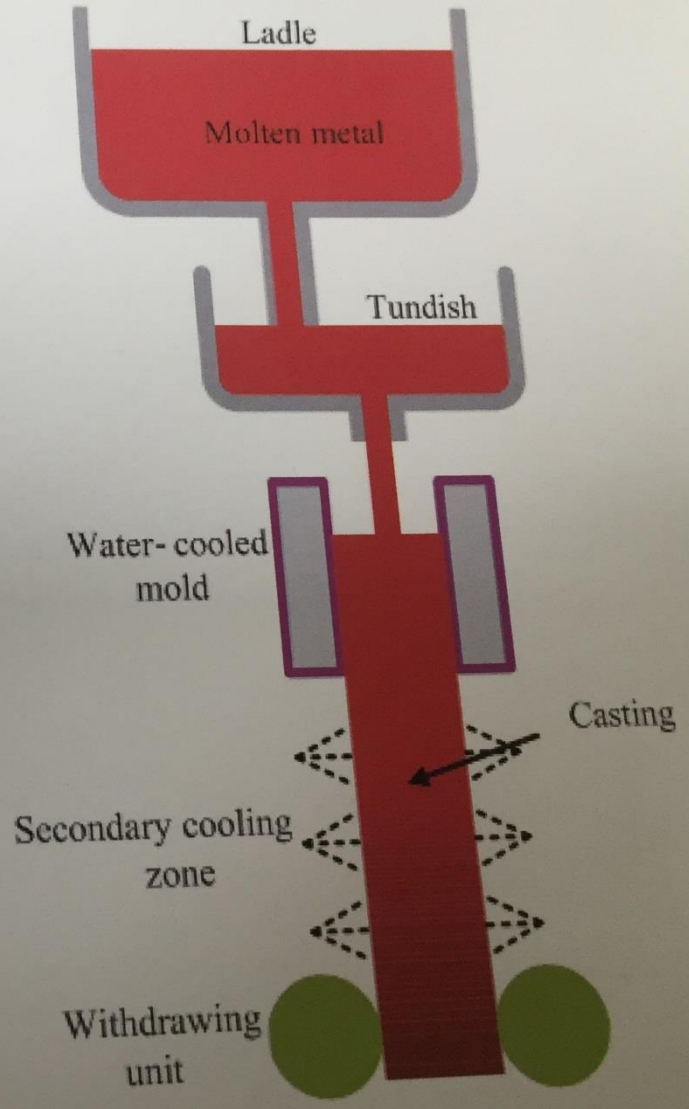
Crystalline Materials

Metallic casting is a well established method of producing components from liquid metal exploiting the metals transformation from the liquid state (where the atoms are randomly dispersed) to the solid CRYSTALLINE state



Continuous casting





Concast

https://www.youtube.com/watch?v=d-72gc6I-_E

Metallic Casting Processes

- Sand Casting
- Gravity Die Casting
- Pressure Die Casting
- Investment Casting

Sand Casting

Things to consider

- Quality of the casting surface required
- Dimensional accuracy of the casting required
- Number of castings required per order
- Type of pattern and core box equipment needed
- Cost of making the mould
- How the selected process will affect the design of the casting

Moulding Processes

- Sand Casting
- Permanent mould
- Ceramic
- Rapid prototyping

Sand Casting

- Mould produced by shaping refractory material to form cavity
- Molten metal poured into cavity
- Metal solidifies
- Casting removed
- Mould must be strong enough to take the molten metal
- Mould must permit gases in the mould to escape to air

Green Sand Moulding

- Most common method for metals
- Granular refractory sand coated with bentonite clay, water and additives
- Additives help harden and hold the mould shape to withstand the pressures of the molten metal.
- The green sand mixture is compacted
- by hand or through mechanical force around a pattern to create a mould.

Chemically Bonded Moulding Systems

- Widely used
- Economic
- Improved productivity
- Unique chemical binder and catalyst to cure and harden mould
- Some processes require heat to facilitate the curing mechanism

Gas Catalyzed or Coldbox Systems

- Cold box systems utilize family of binders
- Catalyst not added to sand mixture
- Catalyst in form of gas or vapour added to sand and resin
- Mixture won’t cure until it is brought into contact with a catalyst agent

10 Rules for good castings

1. Start with a good quality melt
2. Don’t make the meniscus go too fast – max 0.5m/s for most metals
3. Don’t stop the meniscus.
4. Avoid bubbles
5. Avoid core blows
6. Avoid shrinkage
7. Avoid convection
8. Reduce segregation
9. Reduce residual stress
10. Provide location points

Complete Casting Handbook John Campbell