THE PURPOSE OF A BLAST FURNACE IS TO CHEMICALLY REDUCE AND PHYSICALLY CONVERT IRON OXIDES INTO LIQUID IRON CALLED HOT METAL. THIS PARTICULAR PROCESS IS THE DOMINATING IRONMAKING ROUTE FOR PROVIDING THE RAW MATERIALS FOR STEELMAKING.

INTRODUCTION TO BLAST FURNACE

ZONES OF THE BLAST FURNACE

- **THROAT**: The burden surface at the top of the blast furnace
- **SHAFT**: Where the ores are heated and reduction reactions start
- **BELLY OR BOSH PARALLEL**: The short vertical section
- **BOSH**: The ore reduction completes, and the ores are melting down
- **HEARTH**: Where the molten materials are collected and tapped via the tap holes
ZONES OF BLAST FURNACE

MAIN COMPONENTS

TUYERES AND BUSTLE PIPE:
The bustle pipe is a large diameter doughnut shape pipe encircling the furnace. It feeds hot air to the tuyers. The temperatures of the hot blast range from 900 °C to 1250 °C.

Schematic View of Tuyeres and Bustle Pipe

ZONES OF BLAST FURNACE

AUXILIARY COMPONENTS

CHARGING SYSTEM

The materials usually held in hoppers at the top of the furnace until a charge, usually consisting of some type of metallic, coke and flux have accumulated. The precise filling order is developed by the blast furnace operators carefully control gas flow and chemical reactions inside the furnace.

Double Bell Charging

BELL LESS TOP CHARGING

ZONES OF BLAST FURNACE

AUXILIARY COMPONENTS

HOPPERS: For temporarily storing these raw materials
BELT CONVEYORS: For transporting raw materials to the furnace top
BF TOP PRESSURE RECOVERY TRIBUNE: A BF usually operated with a furnace top pressure of about 250 KPA. The recover the energy from the large volume of high pressure exhaust gas. The BF is equipped after dust removal, with top pressure recovery tribune (TRT) for generating electric power by utilizing the pressure differences between the furnace top and gas storing holder.
DUST REMOVAL: Equipment for dust removal and recovery.
CASTHOUSE: Where the molded iron and remaining slag separated before the iron is puried into torpedo car or ladle for transport to further refinement.

ZONES OF BLAST FURNACE

AUXILIARY COMPONENTS

BF-TOP PRESSURE RECOVERY TRIBUNE: A BF usually operated with a furnace top pressure of about 250 KPA. The recover the energy from the large volume of high pressure exhaust gas. The BF is equipped after dust removal, with top pressure recovery tribune (TRT) for generating electric power by utilizing the pressure differences between the furnace top and gas storing holder.
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ZONES OF BLAST FURNACE

PRIMARY REDUCTION ZONE:
The upper part of shaft, where higher valency iron oxides are reduced. Temperature ranges from 400 °C to 1000 °C

THERMAL RESERVE ZONE:
The lower part of the shaft zone, where the temperature is maintained at about 1000-1200 °C. In this zone, reduction of wustite to metallic iron takes place

COHESIVE ZONE:
Extends from above bosh near the wall up to middle part of stack in the center of the BF. The materials has reached about 1200 °C start to soft en and melt except coke particles
ZONES OF BLAST FURNACE

ACTIVE COKE ZONE:
BENEATH THE COHESIVE ZONE, WHERE THE FINAL REDUCTION TO METALLIC IRON COMPLETES, MELTS OF SLAG AND HOT METAL FROM AND DRIP THROUGH THE COKE LAYER

DEAD MAN:
A POROUS PACKED BED OF UNREACTED COKE PARTICLES SITTING OR FLOATING IN THE HEARTH. CARBURIZATION OF HOT METAL TAKE PLACE WITHIN THE DEAD MAN

CHEMICAL REACTIONS

DIRECT REDUCTION

1) \( \text{FeO} + \text{CO} = \text{Fe} + \text{CO}_2 \)
2) \( \text{CO}_2 + \text{C} = 2\text{CO} \)
TOTAL: \( \text{FeO} + \text{C} = \text{Fe} + \text{CO} \)

DIRECT REDUCTION USES CARBON AS THE REDUCTANT AND GENERATES EXTRA CO GAS; DIRECT REDUCTION COSTS A LOT OF ENERGY

INDIRECT REDUCTION

IT IS ALSO CALLED GAS REDUCTION. GAS REDUCTION TAKES PLACE BETWEEN THE CO OF H2 WITH SOLID BURDEN MATERIALS OF IRON OXIDES. IT REMOVES ABOUT 2/3 OF THE TOTAL OXYGEN IN THE IRON ORE. THE INDIRECT REDUCTION REACTIONS WITH CO ARE;

HEMATITE: \( 3\text{Fe}_2\text{O}_3 + \text{CO} = 2\text{Fe}_3\text{O}_4 + \text{CO}_2 \)
MAGNETITE: \( \text{Fe}_3\text{O}_4 + \text{CO} = 3\text{FeO} + \text{CO}_2 \)
WUSTITE: \( 2\text{FeO} + \text{CO} = \text{FeO}_0.5 + \text{CO}_2 \)
PULVERIZED COAL INJECTION

- The injection of auxiliary reductants such as coal, oil, and natural gas is used to lower the cost of hot metal. Coal is the most commonly used and allows cost savings and higher blast temperatures. Coal injection leads to increased productivity from using oxygen enriched blast.

- Coal injection is categorised by their volatile matter content: 6-12% is classified as low volatile, 12-30% as mid volatile and over 30% as high volatile coal.

HOT METAL PRETREATMENT

The process in which impurities are removed from the hot metal before BOS are called hot metal pretreatment. At present, an integrated process of smelting in the BF, hot metal pretreatment, decarbonizing in the BOS, and the secondary refining has become the standard manufacturing process for high-grade steels.

HOT METAL PRETREATMENT

1. Desiliconization: Is therefore conducted as a pretreatment process by adding iron oxides such as mill scale and sintered ore fines to hot metal in the runners in the casthouse of the BF or in the transfer vessel.

2. Slag separation

3. Dephosphorization: Is usually carried out after desiliconization reaction proceeds more quickly at lower silicon contents.

4. Slag separation

5. Decarbonization

6. Slag recycling
ORE AND COKE: TO PRODUCE ONE TONNE OF HOT METAL A TOTAL OF ABOUT 1,600 IRON BEARING AS SINTERED ORE, LUMP ORE AND PELLETS ARE REQUIRED AND IT CONSUMES ABOUT 380 KG OF COKE AS THE REDUCTANT. THE ORE AND COKE ARE CHARGED IN ALTERNATE LAYERS FROM THE TOP OF THE BF.

APPROXIMATELY 1000 Nm³/tonne HOT METAL OF HOT BLAST IS ALSO BLOWN THROUGH THE TUYERES AFTER PREHEATING TO 1150-1250 °C AT THE HOT STOVES. THE HUMIDITY AND THE OXYGEN CONCENTRATION OF THE HOT BLAST ARE ALSO CONTROLLED.

SINTERING AND COLD STRENGTH

SINTER IS A METHOD OF FUSING IRON ORE FINES INTO THE PARTICLES SUITABLE FOR CHARGING INTO THE BLAST FURNACE. THE LIME (CAO) IN THE SINTER IS ADDED AS A FLUX TO THE BLAST FURNACE AND SINTER IS CATEGORIZED. MEAN SINTER SIZES RANGE FROM 15 TO 25 MM AT THE SINTER PLANT.

COLD STRENGTH

LOW COLD STRENGTH RESULTS IN A HIGH FINES RATE.

MELTING PROPERTIES AND COKE

MELTING PROPERTIES

THE MELTING OF SINTER IS DETERMINED BY THE CHEMICAL COMPOSITION. SINTER START SOFTENING AND MELTING AT 1200-1250 °C. VERY BASIC SINTER MELTS AT HIGHER TEMPERATURES OF 1300 °C AND IF THE FeO CONTENT IS VERY LOW, MELTING TEMPERATURES CAN EXCEED 1500 °C.

COKE

THE AIR BLOW INTO THE BLAST FURNACE IS PRE-HEATED TO 100-1250 °C IN THE HOT BLAST STOVES. THE STOVES WORK IN CYCLES, FIRST THE REFRACTORY BRICKS IN STOVE ARE HEATED BY BURNERS USING BF GAS. THEN THE COLD BLAST BLOWN IN AND THE HEAT STORED IN THE BRICKS IS TRANSFERRED TO THE GAS. THE HOT BLAST IS DELIVERED TO THE BF VIA A HOT BLAST MAIN, BUSTLE PIPE AND THE TUYERES.

AT THE TOP OF THE FURNACE THE BLAST FURNACE GAS IS HOT AND CONTAINS A LARGE AMOUNT OF FINE PARTICLES. TO REMOVE THESE, THE GAS IS LED VIA DOWNCOMER TO A DUST CATCHER AND WET CLEANING SYSTEM.

SLAG IS FORMED THE GANGLUE MATERIALS OF THE BURDEN AND THE ASHES OF THE COKE AND OTHER AUXILIARY REDUCTANTS. DURING BF PROCESS, PRIMARY SLAG DEVELOPS TO A FINAL SLAG.

FOR MAIN COMPONENTS; SILICON DIOXIDE, CALCIUM OXIDE, MAGNESIUM OXIDE AND ALUMINUM OXIDE MAKE UP ABOUT 96% OF THE SLAG.

THE MINOR COMPONENTS ARE MAGNESIUM OXIDE, TITANIUM DIOXIDE, POTASSIUM OXIDE, SODIUM OXIDE, SULFUR AND PHOSPHORUS.

HOT METAL IS THE MAIN PRODUCT OF THE BF PROCESS. IT IS CARBON SATURATED IRON WITH A NUMBER OF IMPURITIES SUCH AS SILICON, MANGANESE, SULFUR AND PHOSPHOROUS. IT IS TAPPED FROM THE BF HEARTH AT A TEMPERATURE BETWEEN 1480-1520 °C. A TYPICAL COMPOSITION OF HOT METAL CAN BE SEEN IN THE TABLE.
THE REDUCTION OF IRON ORE BY CARBON AND HYDROGEN GASES IS A VERY COMPLICATED PROCESS. FOR A BETTER UNDERSTANDING OF THE FACTORS INFLUENCING THE REDUCIBILITY OF THE ORES, SINTERS AND PELLETS, HERE IS A VERY SIMPLIFIED VIEW OF RATE-CONTROLLING REACTIONS. IN MOST CASES, THE IRON ORE IS IN THE HEMATITE FORM AND REDUCTION STARTS FROM HEMATITE AND PROCEED IN THE FOLLOWING ORDERS:

HEMATITE → MAGNETITE → WUSTITE → METALLIC IRON

HEMATITE: $3\text{Fe}_2\text{O}_3 + \text{CO} \rightarrow 2 \text{Fe}_3\text{O}_4 + \text{CO}_2$

WHEN THE COKE AND HEMATITE IS HEATED AND REACTS WITH CARBON MONOXIDE, IT IS TRANSFORM TO MAGNETITE. CARBON DIOXIDE AND WATER WHICH EVAPORATES INSTANTLY.

MAGNETITE: $\text{Fe}_3\text{O}_4 + \text{CO} \rightarrow 3\text{FeO} + \text{CO}_2$

MAGNETITE TURNS INTO WUSTITE.

WUSTITE: $2\text{FeO} + \text{CO} \rightarrow 2\text{FeO}_0.5 + \text{CO}_2$

WUSTITE TURNS INTO METALLIC IRON.
CONTROL ARCHITECTURE LAYOUT

LEVEL 0: FIELD INSTRUMENTATION

LEVEL 1: PROGRAMMABLE LOGIC CONTROLLER (PLC) AND/OR DISTRIBUTED CONTROL SYSTEM (DSC) SEQUENCING, LOGICAL CONTROL AND ALARMING

LEVEL 2: PC SYSTEM AND WORKSTATIONS ONLINE MODELING, OFF-LINE MODEL AND SUPERVISORY CONTROL

LEVEL 3: MAINFRAME PLANT INFORMATION SYSTEM

BLOWING IN PROCESS

THE PROCESS OF STARTING A BLAST FURNACE IS CALLED BLOWING IN AND IS MADE UP OF SEVERAL STEPS:

1) DRYING
2) FILLING
3) LIGHTING

BLOWING OUT PROCEDURE

1) DURING BLOWING DOWN THE FURNACE IS OPERATED WITHOUT CHARGING UNTIL THE BURDEN LEVEL REACHES APP. THE TUYERE LEVEL.
2) WATER SPRAYS ARE INSTALLED AT THE TOP OF THE FURNACE TO CONTROL THE TOP GAS TEMPERATURE AND ONE OR MORE LEVELS OF STEAM SPRAYS ARE INSTALLED ON LOWER LEVELS FOR COOLING AND MAINTAINING THE PRESSURE.
3) THE STEAM SPRAYS ARE ACTIVATED WHEN THE BURDEN LEVEL HAS PASSED.
4) THE BLAST RATE AND TEMPERATURE REDUCED AS THE BURDEN LEVEL LOWERS TO CONTROL THE TOP GAS TEMPERATURE AND ITS OXYGEN AND HYDROGEN CONTENT.
5) FINALLY DRAINING THE SALAMANDER. THE SALAMANDER IS THE IRON PRESENT IN THE HEART BELOW THE TOP HOLES AND IS USUALLY DRAINED. IF PERMITTED TO SOLIDIFY, BLASTING IS REQUIRED TO REMOVE THE CHUNK OF SOLID IRON. THE SALAMANDER IS TAPPED THROUGH A HOLE IN THE BRICKWORK OF THE FURNACE BOTTOM CREATED BY DRILLING AND THE LAST PART WITH AN OXYGEN LANCE.

IRREGULARITIES OPERATION

DURING BLAST FURNACE OPERATION IRREGULARITIES CAN OCCUR, CAUSING CONSIDERABLE CONCERN AND CAN LEAD TO SERIOUS TROUBLE IF NOT HANDLED CORRECTLY. THE MOST COMMON IRREGULARITIES OCCURRING ARE:

1) SLIP
2) SCAFFOLDING
3) CHANNELING
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