FERROUS METALS

Outline

- Wrought Iron (Prehistoric Era to 1500 AD)
- Pig Iron & Molten “Cast” Iron
- Blast Furnace
- Mineral Fuels
- Puddling Furnace
- Bessemer & Thomas Processes
- Basic Oxygen Process
- Siemens Process & Open-Hearth Furnace
- Electric Furnaces

Classifications

- Open-Hearth Iron & Wrought Iron
  - Few Hundredths Of 1% Carbon
- Steels
  - 0.04 to 2.25% Carbon
- Cast Iron, Malleable Cast Iron, & Pig Iron
  - 2 to 4% Carbon
- White-Heart Malleable Iron
  - Virtually No Carbon

Iron Characteristics

- Fourth Most Abundant Element In World
- Iron Ores
  - Dusty Reddish-Brown Rock
  - Mixture Of Iron & Oxygen (Iron Oxide)
    - Iron, Iron, Strong Affinity For Oxygen, -- Oxy-
      - Carbon, Iron, Strong Affinity For Oxygen
    - Carbon, Iron, Virtually No Carbon
  - Small Quantities Of Other Elements
  - 25 to 75% Iron

Wrought Iron (Before 1500 AD)

- Beginnings - Speculation (Absence Of Facts)
  - Accidental Smelting Of Iron Ores
  - Iron, Ore, Stones, Reduced To Iron, By Wood Fire
  - Forced, Benefit, High, Wind
  - Hammering, Iron, White, Hot, To Produce Tools
- Iron Implements - Egypt (3000 BC)
- Hardening By Heat Treatment - Greeks (1000 BC)
- Spread To Europe & Britain (1000 BC)
- Fibrous Structure - Like Wood
- Shaped & Welded By Hammering While Hot

Wrought Iron (Before 1500 AD)

- Early Production - Bloomery
  - Small Furnace Made Of Clay
  - Heated By Charcoal Fire
  - Forced Bellows
  - Charcoal & Iron Ore Fed Through Aperture At Top
  - Oxygen In Ore & Carbon Formed Gas That Burned a Blue Flame
  - After Oxygen Burnt Off Ore, Tapped From Bottom
  - Bloom - Small, Spongy Ball Of Iron Produced
  - Hammered On Anvil
    - Drive, Beat, Shape, Weld, & Consolidate Iron
Wrought Iron (Before 1500 AD)
- Bloomery
  - Never Operated On A Large Scale
  - Produced Iron Containing About 3% Slag & 0.1% Other Impurities
- Accidental Production Of Steel
  - Heat wrought iron & charcoal in clay boxes for several days
  - Absorbed carbon to produce true steel

Early Blast Furnace
- First Great Step in Iron Production
  - Introduced in Liege, Belgium (Late 1400s)
  - Reached England in 1500s
  - Short square chimney built of brick or stone
    - 10 to 16’ high
  - Similar to Bloomery, only bigger
    - Operated at higher temperature
    - Higher ratio of charcoal to ore
    - Iron absorbed more carbon from blast of air
    - Produced molten (cast) iron

Early Blast Furnace
- Molten (Cast) iron accumulated at bottom
  - Tapped at intervals
- Molten (Cast) iron channeled to form “Pigs”
  - Pig iron
- As charcoal & iron are used, more is added at top
- Limestone was added - “Flux”
  - Combined with waste materials
  - Formed molten waste - “Slag”

Pig Iron
- As produced from blast furnace, contains
  - Iron, 92%
  - Carbon, 3 to 4%
  - Silicon, 0.5 to 3%
  - Manganese, 0.25 to 2.5%
  - Phosphorous, 0.04 to 2%
  - Sulfur, trace amounts

Molten “Cast” Iron (1500 - 1700)
- Few uses - must be cast on site at time
  - Cast iron cannons - Sussex (1543)
- Molten iron went through second process
  - Finery
    - Produce wrought iron
    - Rational was increased production
    - Blast furnace could make 10 times Bloomery
  - Finery - Furnace
    - Charcoal as fuel & waterwheel-driven bellows
    - Cast iron re-melted to drive off carbon

Finery
- Produced large pieces of wrought iron
  - Led to problems
  - Ironworkers needed long thin bars
- Power hammer (Late 1500s)
  - Waterwheel-driven
  - Pounded iron into flat thin slabs
- Slitting mill (Late 1500s)
  - Cut slabs into strips
- Rolling mill
  - Sketch - Leonardo da Vinci (1486)
Mineral Fuels

- Till 1700, Charcoal Was Used As Fuel
  - Made By Burning Large Heaps Of Wood
  - Impurities Burn Off In Smoke
  - Cool Quickly With Water
- Coal Was Tried Unsuccessfully In Furnace
  - Patent - Dud Dudley (1600s)
  - Contains Sulfur
  - Sulfur Easily Unites With Iron - Iron Sulfides
    - Makes Iron Brittle When Hot Or Cold

History Of Blast Furnaces

- 1600
  - 85 Charcoal-Fired Blast Furnaces In Britain
- 1788
  - 53 Coke-Fired Blast Furnaces In Britain
  - 24 Charcoal-Fired
- Early 1800s
  - No Charcoal-Fired Furnaces Still Operating

Developments Of Blast Furnaces

- Preheating Of Air Blast - J.B. Nelson (1828)
  - Increased Production
    - Preheat: -- 8 Tons. Coal For 1 Ton. Iron
    - After: -- 2.25 Tons. Coal For 1 Ton. Iron
  - Increased Quality
- Reshaping Furnaces - John Gibbons (1832)
  - Round Hearth - 33% More Productive
- Use Of Waste Gas
  - Inflammable Gas In Produced
  - Preheating Of Hot Air Blast

France

- Montcenis-Le Creusot
  - 1785
  - First French Coke-Fired Blast Furnace
  - Very Slow Dissemination Of Technique From Britain

Developments Of Blast Furnaces

- Bell & Hopper (Cup & Cone) - G. Perry (1850)
  - Multiple Hopper Prevent Loss Of Gas
  - Increasing Oxygen Content Of Hot Air Blast
- Pressurizing Furnaces
  - Throttling The Flow Of Gas From Furnace Vents
  - Increases Pressure To 1.7 atm
  - Better Combustion
  - Post W.W.II
International
Le Creusot, 1865
Gluwitz, Silesia, 1830
Pontypool, 1865

Typical Ironworks
- Mechanically-Charged Blast Furnace
- Corby, Northhamptonshire
- 1900

Typical Blast Furnace
- Components
  - Cylindrical Steel Shell Lined With Refractory
    - No metallic substance, -- Firebrick
    - Approximately 1000, High
  - Shell Is Tapered At Top & Bottom
  - Creates Heat Effect
  - Lower Portion Is Called Bosh
    - Taphole, Opener, Collar, Tapree. -- Hot Air Blast
    - Holes At Bottom Are Tapped
    - Dumper, slag
    - Issue -- Molten Pig. Iron. To Foundry
  - Top Portion Lets Gases Escape (Vent)

Operation
- Operate Continuously
- Small Charges Are Introduced At 10-15 Minutes
- Spontaneous Combustion Of Charge
- Slag Is Tapped Every 2 Hours
- Molten Iron Tapped Five Times A Day
- Hot Air Enters At 1000 To 1600°F
- Waste Gases Are Recirculated?