NON-FERROUS METALS

Non-Ferrous Metals

- Copper
- Tin & Bronze
- Lead & Silver
- Brass & Zinc
- Nickel
- Aluminum & Magnesium
- Beryllium & Titanium
- Niobium & Columbium
- Cobalt, Tantalum & Chromium
- Platinum

Categories

- Precious Metals
  - Gold, Silver, Platinum
- Base Metals
  - Old: Iron, Tin, Copper, Zinc, Lead
  - New: Nickel, Magnesium, Cobalt, Aluminum
- Specialty Metals
  - Niobium, Chromium, Beryllium, Titanium, Tantalum
- Pure Alloys
  - Bronze, Brass

Processing Considerations

- Melting Point
- Boiling Point
- Specific Gravity
- Atomic Bonds
- Reactivity
- Solubility

Copper

- General
  - Element, Cu
  - Melts At 1981°F
  - Boils At 2567°F
  - Specific Gravity = 8.9
  - Brownish-Red Color
- History
  - Prehistoric People
  - Egypt, Asia Minor, China, Cyprus, Crete, Am. Indians

Copper (Continued)

- Properties
  - Conducts Electricity & Heat
  - Resists Corrosion
  - Malleable & Ductile
  - Tensile Strength - 60 ksi
- Uses
  - Coins
  - Wire
  - Ornamental
  - Sheathing

Copper (Continued)

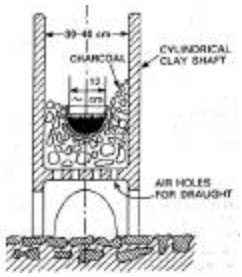
- Metallurgy
  - Native Copper
    - Crushed, Washed, & Cast In Bars
    - Oxides & Carbonates Are Reduced With Carbon
  - Sulfide Ores (Chalcopyrite & Bornite)
    - 1% < Copper < 12%
    - Reverberatory Furnace Yields Crude Metallic Copper
      - 98%
    - Electrolysis Produces 99.9% Purity

Copper (Continued)

- Melted Native Copper
  - Heat From Above By Charcoal Fire
  - Lens-Like Ingot In Clay Lined Saucer Beneath Fire Bed
  - Forced Draught Or Chimney
- Crucible Furnaces
  - Vertical Cylindrical Clay Shaft
  - Crucible Surrounded By Charcoal In Shaft
  - Free Draught
  - Used For Casting

Copper (Continued)

- Earliest Known Crucible Furnace
- Reconstruction
  - 3300 - 3000 BC
  - Chalcolithic Site
  - Abu Matar, Beersheba
  - Perrot (1951)
- Natural Draught Furnace
- Remelting Impure Copper



Copper (Continued)

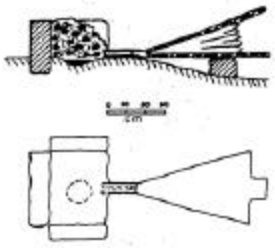
- Melting & Casting Native Copper
  - Originated In Anatolia, Turkey (5000 to 4000 BC)
  - Spread From Asia Minor
  - First Copper Artifacts In Sialk, Iran (4500 BC)
  - Egyptian Artifacts (5000 to 4000 BC)
  - Supplies Of Native Copper Became Inaccessible To Supply Demand
  - Copper Artifacts After 3500 BC Contained Base Metal Impurities
    - Thus, Extracted From Ore

Copper (Continued)

- Smelting Of Oxide & Carbonate Copper Ores
  - Easily Smelted In Primitive Furnaces
  - Separate Copper, Iron & Other Unwanted Ores
  - Chalcolithic Smelting Furnaces At Timna (3000 BC)
    - No Top Hole & No Ingots Found
    - Metal Never Separated From Slag
  - Egyptians At Timna (1200 BC)
  - Reached Zenith At Timna (1100 BC)
- Smelting Of Sulfide & Arsenic Copper Ores

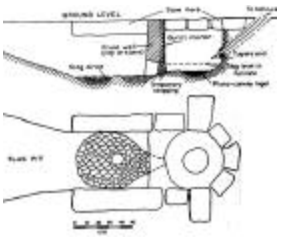
Copper (Continued)

- Egyptians At Timna
- 1200 BC
- Reconstruction Of Remains Of Smelting Furnace
- Cooper Settles To Bottom Of Furnace Below Slag
- Plane-Convex Ingots



Copper (Continued)

- Timna (1200 BC)
- Heated From Above
- Copper & Slag Tapped Simultaneously To Bed Of Sand
- Tap Hole For Slag



Tin

- General
  - Element, Sn
  - Melts At 450°F
  - Boils At 4100°F
  - Specific Gravity = 7.28
- History
  - Tombs Of Ancient Egyptians
  - Exported From Cornwall, England

Tin (Continued)

- Properties
  - Highly Malleable & Ductile > 212°F
- Uses
  - Tin Plating
  - Tin Cans
  - Alloying
    - Bronze (Tin & Copper)
    - Solder (Tin & Lead)
    - With Titanium

Metal Working

- Annealing
  - About 5000 BC
  - Heat Up Metal, Hammer, Cool Down (Repeat)
  - Used Ordinary Wood Fires
  - Without Heat Metal Becomes To Hard & Brittle
- Smelting
  - Reduce Copper Ores To Copper
  - Two-Chamber Pottery Kiln
- Alloying
  - Result of Smelting Process (About 3000 BC)
  - Ores Bearing Different Metals

Bronze

- History - Well Established By 1500 BC
  - Arsenic Coppers Decline (3000 BC)
  - Iran - 2.5% Tin (3000 BC)
  - Sumeria - 8 to 10% (3000 - 2500 BC)
  - Egypt - 8 to 10% (2500 - 2000 BC)
  - Thailand - 8 to 10% (2000 BC)
  - China - 8 to 10% (2800 BC)
  - England (2200 BC)
  - Italy (1850 BC)
  - Spain (1700 BC)

Bronze (Continued)

- Uses In Ancient world
  - Weapons & Cutting Tools
    - Swords
    - Spears
    - Arrowheads
    - Shields
    - Adzes & Axes
  - Bowls & Cauldrons
  - Furnishing - Greece & Rome
    - Bed & Table Frames
    - Tripods & Lamp Stands

Bronze (Continued)

- Casting Techniques
- Rocking Crucible
- 1600 - 1200 BC
- Greek Islands
- Sinai Region

Chinese Bronzes

- Shang Dynasty (1500 BC) to Ch'in Dynasty (206 BC)
- Artistic Vessels
  - Snakes, Dragons, Etc.
- Angyang (1400 - 1027 BC)
- Weight > 1.6 tons
- Multi-part Mold
  - Pre-fired Clay Segments

Lead

- General
  - Element, Pb
  - Melts At 662°F, Boils At 3164°F
  - Specific Gravity = 11.34
- History
  - Obtained From The Ore Galena
  - Also From Cerussite & Anglesite
  - Anatolian - 6500 BC
- Uses
  - Batteries, Cable Sheathing, X-Rays, Shielding Radioactive Material

Silver

- General
  - Element, Ag
  - Melts At 962°F
  - Boils At 2212°F
  - Specific Gravity = 10.5
- History
  - Extracted From Lead (About 4000 BC)
  - Silver-Rich Lead - Aegean Area
  - Valuable Material Till Roman Empire

Silver (Continued)

- Properties
  - Lustrous (High Polish)
  - Most Malleable & Ductile
  - Excellent Electrical Conductivity
- Uses
  - Jewelry
  - Electrical Components
- Processing
  - Smelting Silver Ores
  - Chemically Precipitating Metallic Silver

Brass

- Origins Are Uncertain (Like Bronze)
- Accidentally From Smelting Process Of Zinc-Bearing Cooper Ores
- Zinc Not Naturally Found With Copper
- Artifacts
  - Cyprus (2000 BC)
    - Copper, Zinc (4%), & Tin
  - China (2000 BC)
    - Copper & Zinc (5%)
  - China (1200 BC)
    - Copper & Zinc (10%)

Zinc

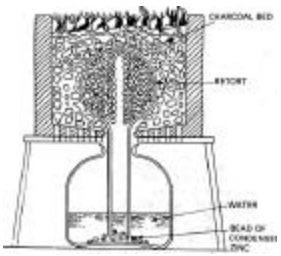
- General
  - Element, Zn
  - Melts At 788°F
  - Boils At 1665°F
  - Specific Gravity = 7.14
  - Silver-White Color
- History
  - Ores Known Since 1000 to 2000 BC
  - Element - Andreas Sigismund Marggraf (1746)
    - German Chemist

Zinc (Continued)

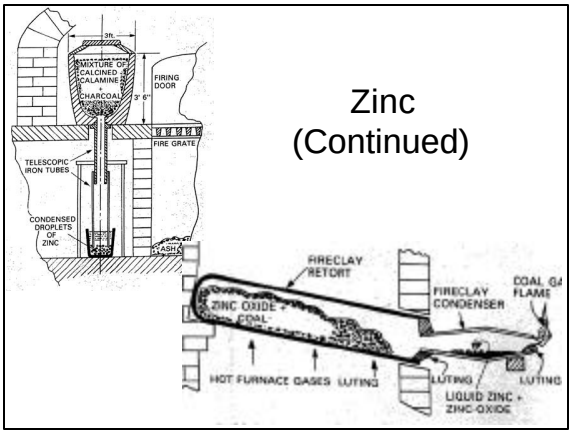
- Properties
  - Brittle
  - Insoluble In Water
  - Soluble In Alcohol, Acids, Alkalies
- Uses
  - Protective Coating
  - Galvanizing
  - Alloying With Copper
  - Die Castings

Zinc (Continued)

- Transform Ores To Oxides By High Temp
- Zinc Boils & Distills In Retort
- Also Can Be Subjected To Sulfuric Acid And Electrolyzed



Zinc (Continued)



Nickel

- Paktong - Chinese
  - Unknown Composition Till 1822 (Fyffe)
    - Cupro-Nickel Alloy
    - Copper, Zinc, & Nickel
  - Chinese Used In 1st Century AD
  - Used In Coins & Cutlery
  - Shipped To England 1700s In Ingot Form
  - Unable To Produce In England
    - Nickel Was Not Identified

Nickel (Continued)

- General
  - Element, Ni
  - Melts At 2651°F
  - Boils At 2730°F
  - Specific Gravity = 8.9 (Same As Copper)
  - Silver-White Color
- History
  - Discovered By Axel Cronstedt (1751)
  - Isolated Metal From Niccolite Ore

Nickel (Continued)

- Properties
  - Hardness
  - Malleable & Ductile
  - Magnetic Below 653°F
- Abundance
  - Largest Supplies In Quebec, Canada
  - Cuba (Meteors), Soviet Union, China, & Australia
  - No Reserves In US

Nickel (Continued)

- Uses
  - Coating - Protective & Ornamental
    - Iron & Steel
    - Electrolysis In Nickel Solution
  - Alloy
    - Steel – Hardness & Strength
    - Automobile Parts – Axles, Crankshafts, Etc.
    - Armor Plate
  - Coins - 25% Nickel, 75% Copper
  - Batteries
    - Nickel–Cadmium

Nickel (Continued)

- Processing
  - Ores Are Smelted In Blast Furnace
    - Ingot Of Copper & Nickel Sulfide
  - Electrolytic Process
    - Copper & Nickel Are Separated
    - Different Voltage To Different Electrolyte
  - Mond Process (Ludwig Mond, England, 1889)
    - Copper Removed In Dilute Sulfuric Acid
    - Nickel Residue Becomes Impure Metallic Nickel
    - Carbon Monoxide Added To Produce Nickel Carbonyl
    - Gas Heated To 392°F, Decomposes
    - Produces Pure Metallic

Aluminum

- General
  - Element, Al
  - Melts At 1220°F
  - Boils At 4473°F
  - Specific Gravity = 2.7
  - Silver-White Color
- History
  - Isolated By Hans Christian Orsted (1825)
    - Danish Chemist
  - Chemical Process Involving Potassium Amalgam

Aluminum (Continued)

- Properties
  - Malleable & Ductile
  - Extremely Reactive
    - Aluminum Oxide
    - Resists Corrosion
    - Do Tarnish Or Rust
- Abundance
  - Most Abundant Metallic Compound In The World
  - Never Found Pure
    - Aluminum Silicates
    - Bauxite (Impure Hydrated Aluminum Oxide)

Aluminum (Continued)

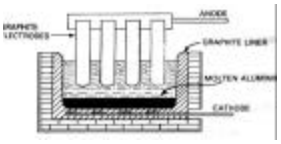
- Uses - US (1989)
  - Containers & Packaging, 31%
  - Building & Construction, 20%
  - Transportation, 24%
  - Consumer Products, 9%
  - Miscellaneous, 16%
- Production - 4 Million tons (1989)
- Cost - $1 Per Pound

Aluminum (Continued)

- Processing
  - Electrolytic Processing (1850s to 1870s)
    - Required Large Amounts Of Electrical Power
    - Decomposing Compounds Depended On Atomic Bonds
    - Most Dissimilar Metals Sort Into Well Defined Voltages
  - Hall & Heroult Simultaneously Discovered Electrolytic Process For Aluminum
  - Bayer Process

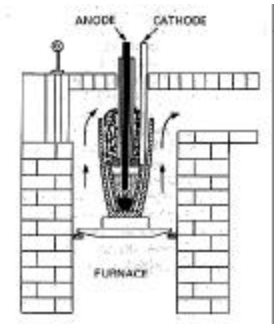
Aluminum (Continued)

- Charles Martin Hall
- 1886
- Alumina Dissolved In Fused Cryolite (Natural Fluoride of Al & Na)
- Sugar In Water Solution
- Alumina/Cryolite Solution Is Good Conductor
- Current Maintained Temperature
- Separated By Electric Current & Cooled



Aluminum (Continued)

- Paul Louis Heroult
- 1886
- Same Process As Hall Except He Added Heat
- Heat Not Necessary
- Cryolite Is Not Consumed



Magnesium

- General
  - Element, Mg
  - Melts At 1200°F
  - Boils At 2025°F
  - Specific Gravity = 1.74
  - Lightest Stable Metal
  - Silver-White
- History
  - Isolated By Sir Humphry Davy (1808)
    - British Chemist

Magnesium (Continued)

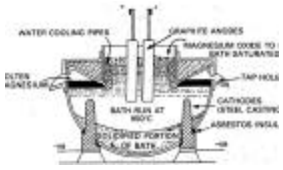
- Properties
  - Malleable & Ductile When Heated
  - Reactive With Acids
  - Reacts With Oxygen Above 1472°F
- Abundance
  - 6th Most Abundant Metallic Compound In The World
  - Found In Carnallite, Dolomite, & Magnesite

Magnesium (Continued)

- Uses
  - "Milk Of Magnesia"
  - Textiles - Refractory & Insulating Material
  - Epsom Salt
  - Cosmetics
  - Alloys
    - Castings
    - Artificial Limbs
    - Lawn Mowers
  - Pure
    - Flash Powders, Incendiary Bombs, Signal Flares

Magnesium (Continued)

- Similar To Aluminum Process
- Molten Magnesium Is Lighter Than Electrolyte



Beryllium

- General
  - Element, Be, Melts At 2349ºF
  - Specific Gravity = 1.85 (Lightweight)
  - Called Glucinium (Sweet Tasting)
- History
  - Discovered By Frederick Wohler (1828)
- Uses
  - High Strength Per Weight
  - Corrosion Resistance At High Temperature
  - Space Applications - Structure & Propellant
  - Nuclear Reactors - Captures Neutrons

Titanium

- General
  - Element, Ti
  - Melts At 3020ºF
  - Specific Gravity = 4.5
  - Also Called Menachite
- History
  - Discovered By William Gregor (1791)
    - British Clergyman
- Uses
  - Pure Titanium Is Very Brittle When Cold
  - Aerospace Applications

Niobium Or Columbium

- General
  - Element, Nb
  - Melts At 4474ºF
  - Specific Gravity = 8.57
  - Steel-Gray
- History
  - Discovered By Charles Hatchett (1801)
    - British Chemist
- Uses
  - Alloying Metal For Stainless Steel
  - Corrosion Resistance At High Temperature

Cobalt

- General
  - Element, Co, Melts At 1495ºF
  - Specific Gravity = 8.9
  - Low Strength, Low Ductility, Hardness
- History
  - Discovered By George Brandt (1735)
    - Swedish Chemist
- Uses
  - Permanent Magnets - Cobalt Steel
  - Tool Bits - Tungsten Carbide

Tantalum

- General
  - Element, Ta
  - Melts At 5425ºF
  - Specific Gravity = 16.6
- History
  - Discovered By Baron Jons Jakob Berzelius (1820)
    - Swedish Chemist
- Uses
  - Corrosion Resistance, Compatibility, & Reactivity
    - Weights & Lab Ware, Electrical Circuits
    - Human Body – Pins & Joints
    - Surgical & Dental Instruments

Chromium

- General
  - Element, Cr
  - Melts At 3375°F
  - Specific Gravity = 7.2
- History
  - Discovered By Louis Nicholas Vauquelin (1797)
    - French Chemist
- Uses
  - Corrosion Resistance, Compatibility, & Reactivity
    - Alloy – Hardness, Strength, Corrosion Resistance
    - Stainless Steel

Platinum

- General
  - Element, Pt
  - Melts At 3222°F
  - Specific Gravity = 21.45
  - Weight & Hardness
  - Powder Metallurgy
- History
  - Discovered By William Brownrigg (1750)
- Uses
  - Chemically Inert - Surgical & Dental
  - Jewelry