Introduction to Copper and Copper Alloys

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Copper Development Association Inc.
May 2013
CDA Mission

The Copper Development Association, Inc. is a not-for-profit trade association that provides technical, market development, education and support services for the U.S. copper industry with a vision towards positively influencing the use of copper and its alloys in today’s society.
Celebrating 50 years of service to the copper industry
Introduction to Copper and Copper Alloys

- History
- Copper Properties
- Production
- Properties
- Alloy Families
- Typical Uses of Select Alloys
- Summary
History – Oldest Metal Known to Man

Figure 1 – Timeline for first commercial use of metals.
The name “Copper”

- The symbol “Cu” comes from cuprum (Latin)
- This is a foreshortened version of aes cyprium (metal from Cyprus)
- In Greek, copper was “chalcos”
- This period in time is the “chalcolithic”
  - means copper - stone
Periodic Table of the Elements

<table>
<thead>
<tr>
<th>Period</th>
<th>Group</th>
<th>Elements</th>
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<tbody>
<tr>
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<td>H</td>
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<td>K, Ca</td>
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<td>Mg, Sc, Ti</td>
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<td>IIIA</td>
<td>Zr, Nb, Mo</td>
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<td>Rb, Sr, Y</td>
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<td>Cs, Ba, La</td>
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<td>Ga, Ge</td>
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<tr>
<td>6</td>
<td>VIIA</td>
<td>As, Se</td>
</tr>
</tbody>
</table>

Numbers in parentheses are mass numbers of the most stable or most common isotopes.
Copper - Properties

Symbol: Cu
Atomic Number: 29
Atomic Weight: 63.546
Standard state: solid at room temperature
Color: copper, metallic

Properties:
- Ductile
- Malleable
- High thermal conductivity
- High electrical conductivity
- Easily alloyed
- Good corrosion resistance
- Readily available
- Highly recyclable
- Antimicrobial
Copper Production
Copper Production
Copper Production - Ores

Two basic types of copper ores:

- sulfide ores
  - Bornite, chalcocite and chalcopyrite
- oxide ores
  - Malachite, azurite and chrysocolla
Copper Production and Recycling

Copper Recycling Flows

Trade

Concentrates/Matte

Blister/Anode

Mining

Production

Mine

Smelter

Refinery

Tailings

By-products/slag/ashes

Scrap Recycling

Scrap for Smelting

Scrap for Refining

incl. low grade
Copper Production and Recycling

Copper Recycling Flows

Trade
- Concentrates/Matte
  - Blister/Anode
    - Refined Copper
    - Alloy Ingot
    - Alloy Metals
    - Semis Net Trade

Mining
- Mine
  - Tailings

Production
- Smelter
  - SX/EW
  - By-products/slag/ashes
    - Refined Copper
    - Fabrication
      - Wire rod plant/Wire mill
        - Brass mill
        - Foundry
        - Other Plants

Refinery
- Refineries
  - Hydromet. Plant
  - Direct Melt
    - Ingots
      - Ingot Maker
        - Scrap
        - Alloys

Scrap Recycling
- Scrap for Smelting
  - Scrap for Refining
    - incl. low grade

Fabrication
- Chemicals
  - Refined Usage

Semis Supply
- New Scrap
  - Low Grade Residues

Refined
Copper Production and Recycling

Copper Recycling Flows

Semis Import → Finished Products

Product Supply → Manufacture
  - Construction
  - E&E Equipment
  - Ind. equipment
  - Transport
  - Consumer/Gen.
  - Other Uses

Manufacture → Finished Products

Low grade from Fabr. → Recycling losses new scrap

Recycling
  - New Scrap
  - Old Scrap

Recycling
Copper Production and Recycling

Copper Recycling Flows

Product Supply:
- Semis Import

Manufacture:
- Construction
- E& E Equipment
- Ind. equipment
- Transport
- Consumer/Gen.
- Other Uses

Finished Products

Net Trade

EOL Products

End-of-Life Management:
- C&D
- INEW
- IEW
- ELV
- WEEE
- MSW & Other

Product Use (Lifetime):
- Copper Reservoir in Use
- Abandoned/Stored/Reused End-of-Life Products

EOL Management adjusted for export/reuse after collection

Recycling:
- New Scrap
- Old Scrap

Low grade from Fabr. 

Recycling losses new scrap

Dissipative Uses

Disposal/Other Uses

Other Metal Loops

Scrap & Low grade Net Trade
Reverberatory Melting Furnace

Fig. 1:17. Longitudinal Section of Melting Furnace (Reverberatory Type) as Used in Welsh Process.
Electric Arc Melting Furnace Types

Fig. 4:2. Outline of Ajax-Wyatt Low Frequency Electric Induction Furnace.

Fig. 4:3. Section Through Ajax-Tama-Wyatt Low Frequency Electric Induction Furnace.
A continuous production process (top) vs. a more conventional production process (bottom)
Development of Properties
Plastic Deformation and Temper

- Metals are made up of crystals
- Deformation of the crystal structure causes internal stress
  - Internal stress in the crystals from rolling, drawing, etc.
  - Temper is determined by processing parameters
- Annealing relieves stresses
Plastic Deformation and Temper

β Polycrystalline Metals

Figure 9.20 Schematic representation of elongation of grains during cold rolling.

As a net result the grains assume a preferred orientation and become elongated in the direction of flow.
Plastic Deformation and Temper

Fig. 10:12. Variation of Mechanical Properties with Percentage Reduction in Thickness of Red Brass.
### Table 7: Temper designations for wrought copper and brass based on cold reduction

<table>
<thead>
<tr>
<th>Nominal temper designation</th>
<th>Increase in B and S gage numbers</th>
<th>Rolled sheet</th>
<th>Drawn wire</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td>Reduction in thickness and area, %</td>
<td>Reduction in diameter, %</td>
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<tr>
<td>¼ hard</td>
<td>1</td>
<td>10.9</td>
<td>10.9</td>
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<tr>
<td>½ hard</td>
<td>2</td>
<td>20.7</td>
<td>20.7</td>
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<tr>
<td>¾ hard</td>
<td>3</td>
<td>29.4</td>
<td>29.4</td>
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<tr>
<td>Hard</td>
<td>4</td>
<td>37.1</td>
<td>37.1</td>
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<tr>
<td>Extra hard</td>
<td>6</td>
<td>50.1</td>
<td>50.1</td>
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<tr>
<td>Spring</td>
<td>8</td>
<td>60.5</td>
<td>60.5</td>
</tr>
<tr>
<td>Extra spring</td>
<td>10</td>
<td>68.6</td>
<td>68.6</td>
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<tr>
<td>Special spring</td>
<td>12</td>
<td>75.1</td>
<td>75.1</td>
</tr>
<tr>
<td>Super spring</td>
<td>14</td>
<td>80.3</td>
<td>80.3</td>
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</table>

(a) True strain equals $\ln \frac{A_0}{A}$, where $A_0$ is the initial cross-sectional area and $A$ is the final area.
Copper Alloys
Copper Alloy Designations

- Unified Numbering System (UNS) Alloy Designations
- UNS System begun in 1974
- Originally only 3 numbers for an alloy
- Now C plus 5 numbers
- Wrought and Cast alloys are included
- CDA Administers UNS Copper Alloys System
Copper Alloys

Strength

Corrosion Resistance

Color

Machinability

Wear Resistance
Wrought Copper Alloy Families

- C100xx-C150xx  Commercially Pure Cu
- C151xx-C199xx  Age Hardenable Cu (w/ Cd, Be, Cr, Fe)
- C2xxxx  Cu-Zn alloys – Brasses
- C3xxxx  Cu-Zn-Pb alloys – Lead brasses
- C4xxxx  Cu-Zn-Sn alloys – Tin bronzes
- C5xxxx  Cu-Sn and Cu-Sn-Pb Phosphor bronze alloys
- C6xxxx  Cu-Al and Cu-Si Bronzes
- C7xxxx  Cu-Ni Copper Nickel and Cu-Ni-Zn Nickel Silver
Cast Copper Alloy Families

- C800xx-C811xx: Commercially Pure Coppers
- C813xx-C828xx: 95-99% Copper
- C833xx-C899xx: Cu-Zn alloys containing Sn, Pb, Mn, or Si
- C9xxxx: Other alloys, including tin bronze, aluminum bronze, copper nickel
Uses of Copper Alloys
Typical Uses of C11000 - Copper

**Architectural**
- building fronts, downspouts, flashing, gutters, roofing, screening

**Automotive**
- gaskets, radiators

**Electrical**
- bus bars, conductivity wire, contacts, radio parts, switches, terminals

**Hardware**
- ball floats, butts, cotter pins, nails, rivets, soldering copper, tacks

**Miscellaneous**
- anodes, chemical process equipment, kettles, pans, printing rolls, rotating band, road bed expansion plates, vats
Typical Uses of C11000 - Copper
Typical Uses of C26000 - Cartridge Brass

**Architectural**
- ✳ grillwork

**Automotive**
- ✳ radiator and heater cores and tanks

**Electrical**
- ✳ flashlight shells, lamp fixtures, switches, reflectors, screw shells, socket shells

**Hardware**
- ✳ eyelets, fasteners, grommets, finish hardware articles (kick plates, lock sets, push plates, etc.)

**Munitions**
- ✳ ammunition components

**Plumbing**
- ✳ plumbing accessories, plumbing brass goods

**Wire**
- ✳ fasteners, pins, rivets, screws, springs
Typical Uses of C26000 - Cartridge Brass
Typical Uses of C36000 - Free Machining Brass

Hardware
- Gears, pinions

Industrial
- Automatic high speed screw machine parts (screws, bolts, nuts, miscellaneous fasteners)
Typical Uses of C36000 – Free Machining Brass
Typical Uses of C51000 - Phosphor Bronze

Architectural
   • bridge bearing plates

Hardware
   • beater bars, bellow, bourdon tubing, clutch disks, cotter pins, diaphragms, fuse clips, fasteners, lock washers, sleeve bushings, springs, switch parts, truss wire, wire brushes

Industrial
   • chemical hardware, perforated sheets, textile machinery, welding rods
Typical Uses of C51000 - Phosphor Bronze
Typical Uses of C70600 - Copper Nickel

**Industrial**
- Condensers, condenser plates, distiller tubes, evaporator and heat exchanger tubes, ferrules, salt water piping
Typical Uses of C70600 - Copper Nickel
Typical Uses of C75200 - Nickel Silver

**Hardware**
- rivets, screws, table flat ware, truss wire, zippers

**Miscellaneous**
- bows, camera parts, core bars, temples

**Miscellaneous**
- base for silver plate, costume jewelry, etching stock, hollow ware, name plates, radio dials
Typical Uses of Nickel Silver – C75200
Overall Markets for Copper Materials
2011 Consumption – Markets

- Building Construction: 43.9%
- Electrical & Electronic: 20.4%
- Transportation Equipment: 16.4%
- Industrial Machinery: 7.5%
- Consumer & General Products: 11.8%

4.98 billion pounds
2.25 million tonnes
2011 Consumption – Products

- **Wire & Cable**: 51.2%
  - 4.98 billion pounds
  - 2.25 million tonnes
- **Foundries & Powder**: 3.4%
- **Rod, Bar & Mechanical Wire**: 15.1%
- **Tube Products**: 14.3%
- **Sheet, Strip & Plate**: 16.0%

Total Consumption: 4.98 billion pounds (2.25 million tonnes)
Summary
Copper Ore

- Powder
- Wire Rod
- Recycl. Copper
- Refined Copper
- Castings
- Alloys
- Rods, Bars, Sections
- Plate, Sheet, Strip, Foil
Copper Ore

- Refined Copper
- Wire Rod
- Recycl. Copper
- Powder

Building & Construction
- Castings
- Electrical & Electronics
- Rods, Bars, Sections
- Alloys
- Plate, Sheet, Strip, Foil

Consumer Products
- Transportation
- Industrial Machinery
Thank you

For more information please contact

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