Legal Statement

The purpose of the information in this presentation is to guide ICA programs and provide members with information to make independent business decisions.
Antitrust Guidelines for Copper Industry Trade Association Meetings

The following guidelines with respect to compliance with antitrust laws of the United States, Japan and European Community¹ are intended to govern the conduct of participants in copper industry trade association meetings, both at the meeting itself and in informal discussions before or after the formal meeting.

**Price:** Competitors should not discuss future prices (including terms of sale) of their products. There is no blanket prohibition against the mention of or reference to current or past prices but limits must be observed. Such references or mentions should occur only when necessary in connection with the development of association programs. For example, reference to a particular price level in comparing the cost of a copper product to a competing product is permitted. Whenever possible, such references should be discussed in advance with legal counsel.

**Competitive Information:** Competitors should not discuss the market share of a particular copper producer or copper fabricator’s products. Furthermore, nothing should be said at a meeting which could be interpreted as suggesting prearranged market shares for such products or producer production levels. The overall market share of copper products may be discussed with regard to competition with non-copper products and general market acceptance.

**New Products:** Competitors should not encourage or discourage the introduction of a new product by another competitor or reveal a particular copper company’s plans to change the production rate of an existing product or to introduce a new product. No company should disclose to another company whether it is in a position to make or market a new product. New products may be discussed in a technical manner or from the standpoints of competition with non-copper products and general market acceptance. In addition, proposed methods for and results of field and laboratory testing can be considered.

**The Role of Legal Counsel:** Legal counsel attends association meetings to advise association staff and other meeting attendees regarding the antitrust laws and to see that none of the matters discussed or materials distributed raise even the appearance of antitrust improprieties. During the course of a meeting, if counsel believes that the discussion is turning to a sensitive or inappropriate subject, counsel will express that belief and request that the attendees return the discussion to a less sensitive area.

A paper entitled ‘Copper Industry Trade Associations and Antitrust Laws’ is available upon request.

10/92, 5/93, 10/10

1. Other foreign competition laws apply to International Copper Association, Ltd. (ICA)’s activities worldwide.
A GLOBAL, DYNAMIC STOCK-AND-FLOW MODEL FOR LEADED BRASS

Dr. Luis TERCERO ESPINOZA
April 2018
Motivation and goals

Status quo

- Dynamic stock-and-flow models for copper are available at the global and regional level
- The models do not track alloying metals such as zinc (Zn), tin (Sn) or lead (Pb)
- Pb is being targeted for more restrictive regulation, which would have a significant impact on the industry
- There is a need for more transparency in the stocks and flows of leaded brass

Therefore, we aimed to

1. Design and implement a dynamic stock-and-flow model for leaded brass
2. Enable calculation of quantitative scenarios for the future of lead content in brass at the global scale
Why is existing (extensive) work on Pb not directly useful?

- Lead-acid batteries: 80%
- Rolled and extruded products: 6%
- Pigments, compounds: 5%
- Misc.: 3%
- Ammunition: 3%
- Cable sheathing: 1%
- Alloys: 2%
- Miscellaneous: 3%

Importance of brass for the copper market

- Brass is used in:
  - Tubes
  - Rods, bars
  - Plate, sheets
  - Mechanical wire
  - Castings

- Adding alloying elements gives a total volume of close to 8 million tonnes of copper alloy
Workflow

- ICA end-use datasets
- General literature, market reports
- Published statistical data
- Previous ICA work on copper alloys

Draft global model

Survey

Refined global copper alloy flow model
Simple sketch of the dynamic model

Primary material

Refined copper / alloying elements input

Alloy semis

Manufacturing of end-use products

Stock of copper alloys in use

New scrap

EoL Scrap

Landfill, incineration, losses to other recycling loops

Historical data (stock buildup) Current status Future scenarios

1950 2016

Recycling

Direct melting

Converter, anode furnace, separate element recovery

Collection & separation

Lifetime distributions

Primary material

Refined copper / alloying elements input

Alloy semis

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Lifetime distributions
Data challenge #1: Diversity of Cu-alloys, many of them containing Pb

<table>
<thead>
<tr>
<th>Generic name</th>
<th>UNS No.</th>
<th>Major alloying elements</th>
<th>Lead content wt%</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Wrought alloys</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Brasses</strong></td>
<td>C20100-C28000</td>
<td>Cu-Zn</td>
<td>&lt;0.3 %</td>
</tr>
<tr>
<td><strong>Leaded brasses</strong></td>
<td>C31200-C38500</td>
<td>Cu-Zn-Pb</td>
<td>2 - 4 %</td>
</tr>
<tr>
<td><strong>Tin brasses</strong></td>
<td>C40400-C48600</td>
<td>Cu-Zn-Sn-Pb</td>
<td>2 - 2.5 %</td>
</tr>
<tr>
<td><strong>Phosphor bronzes</strong></td>
<td>C50100-C52480</td>
<td>Cu-Sn-P</td>
<td>0.5 %</td>
</tr>
<tr>
<td><strong>Leaded phosphor bronzes</strong></td>
<td>C53400-C54400</td>
<td>Cu-Sn-Pb-P</td>
<td>2 - 4 %</td>
</tr>
<tr>
<td><strong>Nickel silvers</strong></td>
<td>C73500-C79830</td>
<td>Cu-Ni-Zn-Pb</td>
<td>0-2 %</td>
</tr>
<tr>
<td><strong>Brazing alloys (copper, silver, phosphor)</strong></td>
<td>C55180-C55284</td>
<td>Cu-P-Ag</td>
<td>&lt;0.3 %</td>
</tr>
<tr>
<td><strong>Aluminium bronzes</strong></td>
<td>C60800-C64210</td>
<td>Cu-Al-Ni-Fe-Sn</td>
<td>&lt;0.3 %</td>
</tr>
<tr>
<td><strong>Silicon bronzes</strong></td>
<td>C64700-C66100</td>
<td>Cu-Si-Sn</td>
<td>&lt;0.3 %</td>
</tr>
<tr>
<td><strong>Copper nickels</strong></td>
<td>C70100-C72950</td>
<td>Cu-Ni-Fe</td>
<td>&lt;0.5 %</td>
</tr>
<tr>
<td><strong>Other wrought copper alloys</strong></td>
<td>C66300-C69710</td>
<td>Cu-Zn-Mn-Al-Ni-Fe-Si-Sn-Co</td>
<td>&lt;0.5 %</td>
</tr>
<tr>
<td><strong>Cast alloys</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Red and leaded red brasses</strong></td>
<td>C83300-C83810</td>
<td>Cu-Zn-Sn-Pb</td>
<td>2-5 %</td>
</tr>
<tr>
<td><strong>Semi red leaded brasses</strong></td>
<td>C84200-C84800</td>
<td>Cu-Zn-Sn-Pb</td>
<td>3-6 %</td>
</tr>
<tr>
<td><strong>Yellow and yellow leaded brasses</strong></td>
<td>C85200-C85800</td>
<td>Cu-Zn-Pb</td>
<td>1-3 %</td>
</tr>
<tr>
<td><strong>Tin bronzes (cast)</strong></td>
<td>C90200-C91700</td>
<td>Cu-Sn-Zn</td>
<td>&lt;0.3 %</td>
</tr>
<tr>
<td><strong>leded tin bronzes (cast)</strong></td>
<td>C92200-C93100</td>
<td>Cu-Sn-Zn-Pb</td>
<td>2-5 %</td>
</tr>
<tr>
<td><strong>High leaded bronzes (cast)</strong></td>
<td>C93200-C94500</td>
<td>Cu-Sn-Zn-Pb</td>
<td>10-20 %</td>
</tr>
<tr>
<td><strong>Nickel-tin-bronzes (cast)</strong></td>
<td>C94700-C94900</td>
<td>Cu-Ni-Sn-Zn-Pb</td>
<td>0.5-4 %</td>
</tr>
<tr>
<td><strong>Manganese bronzes (cast)</strong></td>
<td>C86100-86400</td>
<td>Cu-Zn-Mn-Fe</td>
<td>&lt;0.3 %</td>
</tr>
<tr>
<td><strong>Leaded manganese bronzes (cast)</strong></td>
<td>C86500-C86800</td>
<td>Cu-Zn-Mn-Fe-Pb</td>
<td>0.5-1.5 %</td>
</tr>
<tr>
<td><strong>Leaded copper (cast)</strong></td>
<td>C98200-C98840</td>
<td>Cu-Pb</td>
<td>30 %</td>
</tr>
<tr>
<td><strong>Nickel Silvers (cast)</strong></td>
<td>C97300-97800</td>
<td>Cu-Ni-Zn-Pb</td>
<td>1-6 %</td>
</tr>
<tr>
<td><strong>Other cast alloys (Al, Si, Ni)</strong></td>
<td>-------------------------</td>
<td>Cu-Zn-Mn-Al-Fe-Sn-Co</td>
<td>&lt;0.5 %</td>
</tr>
</tbody>
</table>

the list goes on...
Data challenge #2: Large proportion of “diverse” end uses

- Plumbing
- Building Plant
- Architecture
- Communications
- Electrical Power
- Power Utility
- Telecommunications
- Electrical
- Non Electrical
- Automotive Electrical
- Automotive Non Electrical
- Other Transport
- Consumer & General Products
- Cooling
- Electronic
- Diverse

Water distribution, heating, gas, sprinklers
Valves, fittings, instruments and in plant equipment
Ammunition, clothing, coins and other

ICA/IWCC Global 2017 Semis End-Use Dataset with own additions
Enhancement of the ICA / IWCC dataset by a „lead content matrix“ based on survey input

Accounting of semi-finished goods to end-uses via ICA / IWCC dataset:

<table>
<thead>
<tr>
<th>Diverse</th>
<th>Ammunition</th>
<th>Clothing</th>
<th>Coins</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tube</td>
<td>9%</td>
<td>9%</td>
<td>9%</td>
<td>9%</td>
</tr>
<tr>
<td>RBS</td>
<td>1%</td>
<td>1%</td>
<td>1%</td>
<td>7%</td>
</tr>
<tr>
<td>PSS</td>
<td>9%</td>
<td>4%</td>
<td>31%</td>
<td>3%</td>
</tr>
<tr>
<td>Mech.wire</td>
<td>24%</td>
<td>24%</td>
<td>24%</td>
<td>24%</td>
</tr>
<tr>
<td>Castings</td>
<td>2%</td>
<td>2%</td>
<td>7%</td>
<td>7%</td>
</tr>
</tbody>
</table>

Average lead content of semi-finished goods from survey work with questionnaire based on the „lead content“ matrix:

<table>
<thead>
<tr>
<th>Diverse</th>
<th>Ammunition</th>
<th>Clothing</th>
<th>Coins</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tube</td>
<td>3%</td>
<td>3%</td>
<td>3%</td>
<td>3%</td>
</tr>
<tr>
<td>RBS</td>
<td>3%</td>
<td>3%</td>
<td>3%</td>
<td>3%</td>
</tr>
<tr>
<td>PSS</td>
<td>1%</td>
<td>1%</td>
<td>1%</td>
<td>1%</td>
</tr>
<tr>
<td>Mech.wire</td>
<td>3%</td>
<td>3%</td>
<td>3%</td>
<td>3%</td>
</tr>
<tr>
<td>Castings</td>
<td>4%</td>
<td>3%</td>
<td>3%</td>
<td>3%</td>
</tr>
</tbody>
</table>

ICA/IWCC Global 2017 Semis End-Use Dataset with own additions
Data on brass semis production

- **Primary material**
- **Refined copper / alloying elements input**
  - Alloy semis
  - Manufacturing of end-use products
  - Stock of copper alloys in use
    - New scrap
    - EoL Scrap
      - Collection & separation
      - Stock of copper alloys in use
      - Lifetime distributions
      - Landfill, incineration, losses to other recycling loops

**Recycling**
- Direct melting
  - Converter, anode furnace, separate element recovery

**Historical data (stock buildup)**
- 1950

**Current status**
- 2016

**Future scenarios**

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Global production of semi-finished goods in brass mills

ICA/IWCC Global 2017 Semis End-Use Dataset with own additions
Brass in manufacturing of end-use products

- **Primary material**
  - Refined copper / alloying elements input

- **Manufacturing of end-use products**
  - Alloy semis
  - New scrap

- **Recycling**
  - Direct melting
  - Converter, anode furnace, separate element recovery

- **Storage of copper alloys in use**
  - Collection & separation
  - Landfill, incineration, losses to other recycling loops

- **EoL Scrap**

**Historical data (stock buildup)**
- 1950

**Current status**
- 2016

**Future scenarios**

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Copper alloys by final use

ICA/IWCC Global 2017 Semis End-Use Dataset with own additions
**Build-up of in-use stock**

Primary material

Refined copper / alloying elements input

Alloy semis

Manufacturing of end-use products

Stock of copper alloys in use

New scrap

EoL Scrap

Lifetime distributions

Collection & separation

Landfill, incineration, losses to other recycling loops

Recycling

Direct melting

Converter, anode furnace, separate element recovery

Historical data (stock buildup) Current status Future scenarios

1950 2016

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Build-up of stocks in use

Copper alloy stock accumulation in kt

- Building and Construction
- Power Generation
- Industrial
- Transport
- Consumer and Electronics
- Other Applications

Copper alloy stock accumulation in kt

- non leaded alloy semis
- leaded alloy semis
- average lead content in alloy stocks
Decompose into brass & Pb in brass for 2016

Primary material

Refined copper / alloying elements input

Alloy semis

Manufacturing of end-use products

Stock of copper alloys in use

New scrap

EoL Scrap

Converter, anode furnace, separate element recovery

Direct melting

Historical data (stock buildup) Current status Future scenarios

1950 2016

Landfill, incineration, losses to other recycling loops

collection & separation

Lifetime distributions
Brass (2016)

Total EoL alloy material: 1909 kt

Refined raw materials: 4434 kt - Semis - Semis production: 7682 kt - Fabrication - Total Final use: 6343 kt - Inflow to stock accumulation

Total new scrap: 1339 kt

Pb in brass (2016)

Total lead from EoL alloy scrap flows: 33.5 kt

Primary refined lead: 81.0 kt - Semis - Total lead in Semis: 139.0 kt - Fabrication - Lead content in fabricated products: 114.5 kt - Final use

Lead in new scrap: 24.5 kt
EoL waste management flows in 2016

Primary material

Refined copper / alloying elements input

Alloy semis

Manufacturing of end-use products

Collection & separation

Recycling

Direct melting

Converter, anode furnace, separate element recovery

Stock of copper alloys in use

Landfill, incineration, losses to other recycling loops

EoL Scrap

Historical data (stock buildup)

1950

Current status

2016

Future scenarios
**EoL waste management flows in 2016**

- **Collection of EoL brass scrap**
- **Sorting, separation**
- **Losses to incineration, landfill, other loops**

**Different brass recycling routes**
- **Copper refinery:**
  - Converter, anode furnace, separate copper and alloy element recovery
- **Remelting by ingot makers**
- **Direct melting in brass mills**

**Alloy scrap leaded:** 3397 kt
**Alloy scrap non leaded:** 949 kt

**Collection**
- 2506 kt
- 797 kt

**Separation**
- 366 kt
- 1464 kt
- 119 kt
- 479 kt

**Refinery**
- 891 kt
- 153 kt

**Collection loss**
- 676 kt
- 197 kt

**Separation loss**
Important factors in Pb dilution scenarios

- Overall demand for Cu-alloys in the future
- Ability to meet specifications (provide function) with reduced Pb content
- Possible dilution through:
  1. Reduction of primary input (primary Pb into Cu-alloys)
  2. Share of EoL scrap going to direct re-melting vs. smelting/refining (current options) or removal of Pb from directly re-melted brass (lab scale research)
- Time scale for dilution and shape of change curve (constant rate, accelerating/decelerating rate of reduction, step changes, etc.)
Summary and key conclusions

- The model delivers:
  - Increased transparency of lead flows in copper alloys at a global level
  - It is possible to derive timeframes for dilution of lead content provided plausible scenarios are agreed upon
- Most lead contained in copper alloys is introduced to the alloy as primary material
- Extent to which recycling pathways would change depends on the desired level of dilution
A GLOBAL STOCK-AND-FLOW MODEL FOR LEAD IN COPPER ALLOYS

Dr. Luis TERCERO ESPINOZA
April 2018

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