The purpose of this presentation is to guide ICA programs and provide members information to make independent business decisions.

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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 Community 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.
Copper in Electric Motors and Generators

Krisztina Kalman-Schueler, DMM Advisory Group
on behalf of MetalsPlus

October 2018
Motors & Generators Market in 2017

Copper use

<table>
<thead>
<tr>
<th>Industry</th>
<th>Kt Cu</th>
</tr>
</thead>
<tbody>
<tr>
<td>Automotive</td>
<td>318</td>
</tr>
<tr>
<td>HVACR</td>
<td>369</td>
</tr>
<tr>
<td>Domestic Appliance</td>
<td>393</td>
</tr>
<tr>
<td>Industrial Motors</td>
<td>598</td>
</tr>
<tr>
<td>Other Motors</td>
<td>242</td>
</tr>
<tr>
<td>Generators</td>
<td>213</td>
</tr>
</tbody>
</table>

Total = 2.13 Million Tonnes
**MARKET SUMMARY**

<table>
<thead>
<tr>
<th>End Market</th>
<th>2011</th>
<th>2017</th>
<th>2022</th>
<th>% CAGR 11-17</th>
<th>% CAGR 17-22</th>
</tr>
</thead>
<tbody>
<tr>
<td>Automotive</td>
<td>237</td>
<td>318</td>
<td>434</td>
<td>5.0%</td>
<td>6.4%</td>
</tr>
<tr>
<td>HVACR</td>
<td>302</td>
<td>369</td>
<td>484</td>
<td>3.4%</td>
<td>5.6%</td>
</tr>
<tr>
<td>Domestic Appliances</td>
<td>329</td>
<td>393</td>
<td>469</td>
<td>3.0%</td>
<td>3.6%</td>
</tr>
<tr>
<td>Industrial Motors</td>
<td>471</td>
<td>598</td>
<td>771</td>
<td>4.1%</td>
<td>5.2%</td>
</tr>
<tr>
<td>Other Motors</td>
<td>193</td>
<td>242</td>
<td>302</td>
<td>3.9%</td>
<td>4.5%</td>
</tr>
<tr>
<td>Generators</td>
<td>190</td>
<td>213</td>
<td>267</td>
<td>2.0%</td>
<td>4.6%</td>
</tr>
</tbody>
</table>

**ALL COPPER USE (kt)**

- 2011: 1,722
- 2017: 2,134
- 2022: 2,728
- % CAGR 11-17: 3.6%
- % CAGR 17-22: 5.0%
Application Shares by Alternative Measures

Copper use closer to Value than other measures

<table>
<thead>
<tr>
<th>Value</th>
<th>Number of Units</th>
<th>MW Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Automotive</td>
<td>HVACR</td>
<td>Domestic Appliance</td>
</tr>
<tr>
<td>Industrial Motors</td>
<td>Other Motors</td>
<td>Generators</td>
</tr>
</tbody>
</table>
A Closer Look at Capacity

Over 60% of the market in Motors under 37.5 kW

- FHP Motors
  - Motor 0.75 - 37.5 kW
  - Motor 37.5 - 200 kW
  - Motor 200 - 375 kW
  - Motor over 375 kW

- Generators
- Large
- Medium
- Small (2)
- Small (1)

Total MW = 2,251
Regional Shares of Copper Use

China's Cu use boosted by copper in exported motors

Cu Shares of Motor & Generator Output 2017

- China: 50%
- Other Asia: 25%
- Other Europe & Africa: 3%
- European Union: 10%
- Latin America: 5%
- North America: 7%

Net Import Value (Motors Only)

- Latin America
- North America
- Other Asia
- ASEAN
- N.E. Asia
- China
- India
- Other Europe
- European Union

Net Imports in 2016 ($ billion)
Cu Shares by Motor Type (kt Cu)

AC Asynchronous (induction motors) dominant

Shares 2004-2017

Shares in 2017

Note: Generators excluded from these figures
Aluminium winding wire competes directly with Cu; other materials influence Cu through changed design parameters.

<table>
<thead>
<tr>
<th>Material</th>
<th>kt</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cu Winding Wire</td>
<td>2,052</td>
</tr>
<tr>
<td>Other Copper</td>
<td>82</td>
</tr>
<tr>
<td>Al Winding Wire</td>
<td>400</td>
</tr>
<tr>
<td>Cast Rotor Aluminium</td>
<td>455</td>
</tr>
<tr>
<td>Permanent Magnets</td>
<td>291</td>
</tr>
<tr>
<td>Electrical Steel</td>
<td>11,509</td>
</tr>
</tbody>
</table>

All Material = 14.86 Mt
Excluding Steel = 3.29 Mt

Note: Aluminium figures in kt equivalent, all others as actual kt.
Need to Lower Carbon Footprint Drives Motor Design

Typically, lowering loss means higher copper use

Motor Electricity Use and Loss in the Electricity Market Context

<table>
<thead>
<tr>
<th>Electricity Production (100%)</th>
<th>Electricity Consumption (83%)</th>
<th>Transmission &amp; Distribution Loss (17%)</th>
<th>Electronics &amp; Other (13%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Light (16%)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Heat (16%)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Motors (38%)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Loss in Motors &amp; Driven Systems (17%)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Effective Motor Output (21%)</td>
</tr>
</tbody>
</table>
Load Loss by Motor Size

Focus of load loss, and legislation, 0.75-375 kW

Shares of Load Loss & Other Measures by Motor Size

<table>
<thead>
<tr>
<th>Motor Size</th>
<th>MW Sale</th>
<th>MW in Place</th>
<th>Electricity Use</th>
<th>Loss</th>
</tr>
</thead>
<tbody>
<tr>
<td>FHP Motors</td>
<td>27.1%</td>
<td>22.0%</td>
<td>31.6%</td>
<td>10.2%</td>
</tr>
<tr>
<td>0.75 - 37.5 kW</td>
<td>41.7%</td>
<td>38.7%</td>
<td>25.0%</td>
<td>38.3%</td>
</tr>
<tr>
<td>37.5 - 200 kW</td>
<td>8.4%</td>
<td>14.4%</td>
<td>19.8%</td>
<td>15.1%</td>
</tr>
<tr>
<td>200 - 375 kW</td>
<td>14.6%</td>
<td>12.8%</td>
<td>17.2%</td>
<td>13.9%</td>
</tr>
<tr>
<td>Over 375 kW</td>
<td>8.3%</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Legend:
- FHP Motors
- 0.75 - 37.5 kW
- 37.5 - 200 kW
- 200 - 375 kW
- Over 375 kW
Minimum Energy Performance Standards (MEPS)

IE3 now firmly on the agenda, IE4 standard defined

Select Milestones in Mandatory MEPs Development

- **1997**: US & Canada pass rules for IE2 minimum
- **2004-06**: Early adopters of minimum standards include Mexico, Australia & Korea
- **2008**: China brings in IE1 minimum
- **2010**: USA brings in IE3 ruling (implementation 2016)
- **2011**: EU implements IE2 minimum, replacing voluntary system
- **2012**: China IE2 minimum, with stated plans to implement IE3
- **2014**: EU IE2 with VFD, IE3 without, and forwardplan to bring in IE3 for all motors, scope 0.12-1,000 kW
- **2015**: Japan implements Top Runner IE3 0.75-375 kW
- **2017**: India first mandatory rule: IE2 for industrial motors
Options for Improving Efficiency (1)

Enhance current design, or re-design

1) Optimise Existing Designs

2) Variable Frequency Drives (VFDs)

3) Rare Earth Permanent Magnet (REPM) Solutions
4) Non PM Solutions: Synchronous Reluctance (SynRM) Motors

5) Non PM Solutions: Switched Reluctance (SRM) Motors

6) Non PM Solutions: Copper Rotor Motor
Why Limit Rare Earth Exposure?

Pricing, and critical rare earth supply issues

Type of Permanent Magnet
- All
  - Rare Earth 14%
  - Ferrite 86%
- Motors & Generators
  - Rare Earth
  - Ferrite
- Other

Critical Rare Earths
- All
  - Neodymium Oxide 18%
  - Dyprosium Oxide 1%
  - Other Rare Earths 81%
- Motors & Generators
  - Neodymium Oxide
  - Dyprosium Oxide
- Other

Nd and Dy Price Index
US$ Price Index (2008 = 100)
- Neodymium Oxide
- Dyprosium Oxide

Graph showing price index over time from 2004 to 2018.
Net Impact on Copper Going Forward

Intensity of use now rising, in a fast-growing market

<table>
<thead>
<tr>
<th>Year</th>
<th>Capacity (GW)</th>
<th>Market Value ($BN)</th>
<th>Units (BN)</th>
<th>Copper Use (MT)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2005</td>
<td>1.30</td>
<td>69</td>
<td>3.9</td>
<td>1.36</td>
</tr>
<tr>
<td>2011</td>
<td>1.81</td>
<td>95</td>
<td>5.6</td>
<td>1.72</td>
</tr>
<tr>
<td>2017</td>
<td>2.25</td>
<td>121</td>
<td>7.6</td>
<td>2.13</td>
</tr>
<tr>
<td>2022</td>
<td>2.73</td>
<td>149</td>
<td>9.3</td>
<td>2.73</td>
</tr>
</tbody>
</table>

% CAGR

- 05-11: 5.7%, 3.7%, 4.0%
- 11-17: 5.4%, 4.1%, 4.3%
- 17-22: 6.4%, 5.1%, 4.1%