The switch to aluminum magnet wire is on the agenda of electric motor manufacturers. Many fractional horse power (FHP) motor manufacturers, selling to the appliance, heating, ventilation, and air conditioning equipment industries, are seriously evaluating a switch from copper to aluminum magnet wire. The economics of switching to aluminum are quite straightforward: Copper magnet wire currently contributes up to ten percent to the overall cost of a typical FHP electric motor. At current market prices, switching from copper to aluminum wire can potentially reduce this contribution to less than two percent.

However, to achieve equal conductivity, aluminum wire needs to have a larger cross-sectional area than copper. As a rule, the AWG* has to be reduced by two numbers which means that, for instance, a 20 AWG copper wire could be replaced by 18 AWG aluminum wire. Yet, even on an equal conductivity basis, aluminum is over half the weight of copper. For medium and high volume FHP motor manufacturers in particular, the reduced material cost and the lower motor weight are equally welcome. Looking at the price development, it also appears that aluminum is not subject to the same price increases that can be seen with copper.

Advantages of aluminum magnet wire:

• Aluminum is traditionally 1/4 the cost of copper
• Aluminum is 1/2 the equal conductive weight of copper
• Aluminum is 1/8 the price per unit of conductivity vs. copper
• Aluminum is 1/3 the equal conductive price of copper

between March 2010 and March 2011 the aluminum price increased 12%.

![Image](image-url)
Wire connection technology has to be on a par with the reliability of connector-based interconnection.

How MAG-MATE IDC technology works

In the IDC-based interconnection system, bush-shaped metal terminals are inserted into a continuous strip, and the manufacturer inserts the terminals into a plastic cavity: the plastic cavity absorbs the impact of the metal terminals, and is dimensionally designed to accommodate this impact. The molded plastic grips the wire on each side of the IDC slot, providing a reliable, long-term connection. The opposing side walls of each terminal slot are chamfered, providing friction that maintains constant pressure against the terminal. The terminal is positioned over the magnet wire in the housing cavity by means of an integral wire support or "anvil" feature.

The MAG-MATE metal terminal has two IDC slots with an oblong shape. During this process four gas-tight points of contact are formed. Points A and B represent the wire end position. Therefore TE conducted studies to verify the factors that result in long-term successful IDC termination of aluminum magnet wire. These studies incorporated environmental and mechanical stresses and evaluated the effects of:

- wire end position within IDC slot
- IDC slot compliance
- terminal plating features
- strain relief features

The tests showed a very stable performance of aluminum magnet wire when used in aluminum IDC terminals in the slot and standard strain relief from the plastic cavity offer the best performance for aluminum magnet wire. In this case the groups represent different combinations of slot designs, plating materials, and terminal materials. For applications with space constraints, the terminal can be molded out of the existing body or can be part of a separately attached housing. This molded cavity has two slots at opposing sides with a chamfered lead at the top of each slot. The magnet wire is captured within the two sealed slots to provide virtually no springback and leading to a short termination life. Termination life on aluminum magnet wire is the critical parameter to ensure that the termination process leaves the wire in a compliant region of the connector slot, and TE engineers can specify an optimum insertion depth for an application. Therefore, tests have shown that the interference fit between magnet wire and plastic cavity slots can provide an advantageous solution. The IDC does not require the use of single-beam IDC terminals for aluminum magnet wire terminations because they do not provide the reliability and control needed for such a dynamic conductor as aluminum wire.

The termination of aluminum magnet wire has presented unique challenges for IDC technology. Environmental and mechanical stresses will cause aluminum to experience creep and stress relaxation to a much higher degree than copper. Aluminum wire manufacturers have been able to mitigate the creep and stress relaxation characteristics by developing aluminum-magnet wire with iron, but at a higher cost than traditional aluminum wire. Instead, the MAG-MATE IDC termination can be sized to accommodate for the environmental properties of aluminum without impacting the aluminum alloy, the wire weight - or the termination quality itself. Evaluating the possible influence of connector design modifications

Analysis of the influence of the wire end position revealed that how important the inclusion of standard IDC interconnection technology for magnet wire is. The tests presented demonstrate the need for effective insulation displacement without intensive pre-stripping or soldering. In this case, the groups represent different combinations of slot designs, plating materials, and plastic cavity slots. Other samples included copper magnet wire as a baseline for comparison.

The table in Figure 4 shows the test samples examined for the first time, the insertion depth, and shows the influence of a strain relief feature.

Table 1

<table>
<thead>
<tr>
<th>Test Group</th>
<th>Wire End Position</th>
<th>IDC Slot Compliance</th>
<th>Terminal Plating Features</th>
<th>Strain Relief Features</th>
<th>Insertion Depth (mm)</th>
<th>Influence of a Strain Relief Feature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group 1</td>
<td>A</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>2.5</td>
<td>Positive</td>
</tr>
<tr>
<td>Group 2</td>
<td>B</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>3.0</td>
<td>Positive</td>
</tr>
<tr>
<td>Group 3</td>
<td>C</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>3.5</td>
<td>Negative</td>
</tr>
<tr>
<td>Group 4</td>
<td>D</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>4.0</td>
<td>Negative</td>
</tr>
</tbody>
</table>

Conductors containing replacing copper magnet wire with aluminum wire are welcome to contact TE engineering for design support. Based on 30 years of experience with IDC interconnection technology for magnet wire, and the portrayed in-house studies, TE can optimally apply the principal benefits of IDC technology by aluminum wire usage.

In order to ensure that the termination process leaves the wire in a compliant region of the connector slot, and TE engineers can specify an optimum insertion depth for an application. In addition to that, tests have shown that the interference fit between magnet wire and plastic cavity slots can provide an advantageous solution. The IDC does not require the use of single-beam IDC terminals for aluminum magnet wire terminations because they do not provide the reliability and control needed for such a dynamic conductor as aluminum wire.

Figure 3 compares the average resistance levels of the MAG-MATE terminal on aluminum magnet wire as applied to environmental and mechanical stresses. Some samples were subjected to 100 thermal cycles between the magnet wire and plastic cavity slots. Other samples did not incorporate the strain relief feature. The test group included copper magnet wire as a baseline for comparison. The test group included copper magnet wire as a baseline for comparison.
Wire connection technology has to be in a good with the reliability of copper-based interconnection.

How MAG-MATE IDC technology works

In the IDC-based interconnection system, box-shaped terminals are inserted into a slot. After manual insertion, the terminal is locked into place using a plastic housing. This design provides a reliable connection, minimizing the risk of vibrations and stress relaxation of the interconnection. The unique terminal design with chamfered lead-ins provides a reliable connection, ensuring that the wire is securely held in place.

Terminating aluminum wire magnet

The termination of aluminum magnet wire has presented unique challenges for IDC technology. To overcome these challenges, TE Connectivity designed the MAG-MATE IDC system, which provides excellent pressure control and stress relaxation. This system offers a reliable and durable termination solution, ensuring that the interconnection is reliable and cost-effective.

Widely used for many years, the MAG-MATE IDC system has proven to be an effective solution for magnet wire termination over the past 15 years. TE Connectivity has been successfully driving a superior solution for magnet wire termination over the past 15 years.

The MAG-MATE IDC system is designed to provide a reliable termination, Figure 1. The wire deforms to the slot inside the cavity by means of an integral wire support or “anvil” feature. The terminal is inserted into a plastic cavity using a bobbin or can be part of a separately attached housing. The wire is manually supported, and the terminal is guided into place by means of an integral wire support or “anvil” feature.

Therefore, TE conducted studies to verify the factors that result in long-term successful IDC termination of aluminum magnet wire. Two studies incorporated environmental and mechanical stresses and evaluated the effects of:

- IDC slot compliance
- Terminal pricing features
- Strain relief features
- IDC slot compliance
- Terminal pricing features
- Strain relief features
- IDC slot compliance
- Terminal pricing features
- Strain relief features

The tests showed a very stable performance of MAG-MATE terminations on aluminum magnet wire (see Figure 2). The tests were conducted to take certain precautions during the termination process to ensure a successful termination on aluminum wire, the manufacturer:

- must not over-insert the wire into the IDC slots.
- must incorporate strain relief features in the plastic housing

Details on the influence of the wire end position

Table 1 and Figure 2 both illustrate different test samples, Figure 3 #21 AWG Al C Yes

In order to ensure that the termination process leaves the wire in a complete condition, TE engineers have applied an optimum insertion depth for an application. In addition to this, new test data have shown that terms limits the interference fit between magnet wire and plastic cavity. This avoids an acceptable solution. Finally, TE does not recommend the use of single-bend IDC terminals for aluminum magnet wire terminations because they do not provide the redundancy and control needed for such a dynamic conductor as aluminum wire.

Customers considering replacing copper magnet wire by aluminum wire are welcome to contact TE engineering for design support. Based on 15 years of experience with IDC interconnection technology for magnet wire, and the portrayed in-house studies, TE can optimally apply the principal benefits of IDC technology by aluminum magnet wire termination.

In order to maintain optimal performance, standard connector design (Type 3) offers the best performance. Special sodium plating actively dissipated termination performance on aluminum magnet wire. The combination of a more compliant slot with the special plating (Type 3) clearly produces excellent results. Additionally, enhanced stress relief offered as an improvement over a standard interference fit between the magnet wire and slot in the plastic cavity.

We therefore conclude that the standard MAG-MATE IDC terminal with the wire terminated in the compliant region of the IDC slot and standard stress relief from the plastic cavity offers the best performance for aluminum magnet wire.

Conclusion

These TE studies indicate that FHP manufacturers can switch from copper to aluminum magnet wire and use standard insertion slot design to obtain increased interlock stress intensive pre-stripping or soldering.
Wire connection technology has to be on a par with the reliability of copper-based interconnection. IDC technology (Integrated Circuit Device) is based on a dielectric core, and is fast becoming an integral part of the electronics industry, thanks to its tremendous enhancement on the assembly line. IDC technology has been proved to be an effective alternative to stripping and soldering for magnet wire, providing maximum springback capability and longest life. IDC technology has many prominent advantages, including:• Strain relief features• Terminal plating materials• Terminal geometry• Increased surface area• Improved mechanical stresses• Improved reliability• Increased ease of assembly• Improved conductivity• Reduced labor costs• Reduced material costs

Terminating aluminum magnet wire
The termination of aluminum magnet wire has presented unique challenges for IDC interconnection technology when used in various applications such as medium and high volume manufacturing operations. In magnet wire applications. To meet this demand, Minco/MAG-MATE, TE Connectivity, and the TE connectivity logo are trademarks of the TE Connectivity Ltd family of companies. Other logos, product and company names may be trademarks of their respective owners.

IDC Technology
TE Connectivity’s IDC technology has been successfully driving a superior connector product line for many years. Many leading FHP motor and pump manufacturers around the world use TE Connectivity’s IDC technology to terminate copper magnet wire. This product portfolio is based on integration of technology and knowledge from TE Connectivity. IDC has proven to be an effective alternative to stripping and soldering in thousands of applications for over 60 years.

Table 1
<table>
<thead>
<tr>
<th>Wire size, material</th>
<th>Wire position in plastic cavity</th>
<th>Overall insertion depth</th>
<th>Terminal plating materials</th>
<th>Strain relief features</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 #22 AWG Cu</td>
<td>B</td>
<td>0.900</td>
<td>Copper</td>
<td>No</td>
</tr>
<tr>
<td>5 #21 AWG Al</td>
<td>C</td>
<td>0.900</td>
<td>Indium</td>
<td>Yes</td>
</tr>
</tbody>
</table>

Figure 2
The IDC termination process. When the magnet wire is pre-positioned into the slots of the plastic cavity, the MAG-MATE terminal is placed on top of the wire and the plastic cavity. The wire end position “B” is the standard wire position for aluminum wire, and the wire end position “C” is the standard wire position for copper wire.

Details on the influence of the wire end position
Table 1 and Figure 2 both illustrate different test samples, and strain relief features included in Table 2. Indium plating was used in groups 3 and 4 shown in Table 1 illustrating that over-insertion of the wire into the IDC slot compromises the reliability of the termination. As a result, TE Connectivity now specifies an optimal insertion depth for groups 3 and 4 shown in Table 1. The insertion of the magnet wire into the IDC slot compromises the reliability of the termination. To ensure a successful termination on aluminum wire, the manufacturers:• Must not over-insert the wire into the IDC slots. • Must incorporate strain relief features in the plastic housing.

Figure 3
Testing the possible minimum insertion depths for groups 3 and 4 and measured the resistance of the wire connections for aluminum and copper magnet wire.

Figure 4
In order to ensure that the termination process leaves the wire in a complete ring of the connector, TE engineering has specified an optimum insertion depth for an application. In addition to that, TE has also established that the interference fit between magnet wire and plastic cavity slot can provide an adequate solution. Finally, TE does not recommend the use of single-beam IDC terminals for aluminum magnet wire terminations because they fail to provide the radionic control needed for such a dynamic conductor as aluminum wire.

Consequently, customers considering replacing copper magnet wire with aluminum are welcome to contact TE engineering for design support. Based on 50 years of experience with IDC interconnection technology for magnet wire, and the tremendous results achieved, TE Connectivity can apply the principle of IDC technology to aluminum magnet wire.

Conclusion
These TE studies indicate that FHP motor manufacturers can switch from copper to aluminum magnet wire and use standard insertion depth between the magnet wire and plastic cavity slot. Other studies still need to be conducted to ensure that interference fit between magnet wire and plastic cavity slot can provide an adequate solution. Finally, TE does not recommend the use of single-beam IDC terminals for aluminum magnet wire terminations because they fail to provide the radionic control and structure needed for such a dynamic conductor as aluminum wire.
Magnet Wire Applications

Applying MAG-MATE Insulation Displacement Connection (IDC) Technology to Aluminum Magnet Wire Applications

The switch to aluminum magnet wire is on the agenda of electric motor manufacturers

Many fractional horse power (FHP) motor manufacturers, selling to the appliance, heating, ventilation, and air conditioning equipment industries, are seriously evaluating a switch from copper to aluminum magnet wire. The economics of switching to aluminum are quite straightforward: Copper magnet wire currently contributes up to ten percent to the overall cost of a typical FHP electric motor. At current market prices, switching from copper to aluminum wire can potentially reduce this contribution to less than two percent.

However, to achieve equal conductivity, aluminum wire needs to have a larger cross-sectional area than copper. As a rate the AWG size has to be reduced by two numbers which means that, for instance, a 20 AWG copper wire could be replaced by the 18 AWG aluminum wire. Not even an equal conductivity back, aluminum is one fall the weight of copper. For medium and high volume FHP motor manufacturers in particular the reduced material cost and the lower motor weight are equally welcome. Looking at the price development, it also appears that aluminum is not subject to the same price increase that can be seen with copper.

Advantages of aluminum magnet wire:

• Aluminum is 1/8 the cost per unit of conductivity vs. copper
• Aluminum is 1/2 the equal conductive weight of copper
• Aluminum is 1/3 the weight of copper
• Aluminum wire can potentially reduce this contribution to less than two percent.
• Aluminum wire can potentially reduce this contribution to less than two percent.
• Aluminum wire can potentially reduce this contribution to less than two percent.

Table 3: Parameters for testing magnet wire IDC terminals for aluminum.

<table>
<thead>
<tr>
<th>Group</th>
<th>Wire Size</th>
<th>Terminal Area</th>
<th>Contact Resistance</th>
<th>Terminal Resistance</th>
<th>Insulation Resistance</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>22 AWG</td>
<td>0.0007 in²</td>
<td>0.001 Ohm</td>
<td>0.005 Ohm</td>
<td>5000 Megohms</td>
</tr>
<tr>
<td>2</td>
<td>20 AWG</td>
<td>0.001 in²</td>
<td>0.0015 Ohm</td>
<td>0.008 Ohm</td>
<td>10,000 Megohms</td>
</tr>
<tr>
<td>3</td>
<td>18 AWG</td>
<td>0.0015 in²</td>
<td>0.002 Ohm</td>
<td>0.012 Ohm</td>
<td>20,000 Megohms</td>
</tr>
<tr>
<td>4</td>
<td>16 AWG</td>
<td>0.002 in²</td>
<td>0.0025 Ohm</td>
<td>0.016 Ohm</td>
<td>40,000 Megohms</td>
</tr>
<tr>
<td>5</td>
<td>14 AWG</td>
<td>0.0025 in²</td>
<td>0.003 Ohm</td>
<td>0.021 Ohm</td>
<td>80,000 Megohms</td>
</tr>
<tr>
<td>6</td>
<td>12 AWG</td>
<td>0.0032 in²</td>
<td>0.0035 Ohm</td>
<td>0.026 Ohm</td>
<td>160,000 Megohms</td>
</tr>
<tr>
<td>7</td>
<td>10 AWG</td>
<td>0.004 in²</td>
<td>0.004 Ohm</td>
<td>0.032 Ohm</td>
<td>320,000 Megohms</td>
</tr>
<tr>
<td>8</td>
<td>8 AWG</td>
<td>0.005 in²</td>
<td>0.0045 Ohm</td>
<td>0.040 Ohm</td>
<td>640,000 Megohms</td>
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te.com/products/magnet-wire

FOR MORE INFORMATION

te.com/industrial

TE Technical Support Center

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LatAm:      | +56 (0) 7-9722-0000
Germany:    | +49 (0) 6266-161890
UK:         | +44 (0) 800-826-7666
France:     | +33 (0) 1-5329-6866
Netherlands:| +31 (0) 72-6248-899
China:      | +86 (0) 10-130-6135

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Specifications are subject to change without notice. Consult TE for the latest dimensions and design specifications.

Analysis performed by: Darmstadt, Germany | June 2011

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Applying MAG-MATE Insulation Displacement Connection (IDC) Technology to Aluminum Magnet Wire Applications

The switch to aluminum magnet wire is on the agenda of electric motor manufacturers

Many fractional horse power (FHP) motor manufacturers, selling to the appliance, heating, ventilation, and air conditioning equipment industries, are seriously evaluating a switch from copper to aluminum magnet wire. The economics of switching to aluminum are quite straightforward. Copper magnet wire currently contributes up to ten percent to the overall cost of a typical FHP electric motor. At current market prices, switching from copper to aluminum wire can potentially reduce this contribution to less than two percent.

However, to achieve equal conductivity, aluminum wire needs to have a larger cross-sectional area than copper. As a rule the AWG* has to be reduced by two numbers which means that, for instance, a 20 AWG copper wire could be replaced by a 22 AWG aluminum wire. Not even an equal conductivity basis, aluminum is one half the weight of copper. For medium and high voltage FHP copper motor manufacturers in particular the reduced material cost and the lower motor weight are equally welcome. Looking at the price development, it also appears that aluminum is not subject to the same price increases that can be seen with copper.


*American Wire Gauge

Advantages of aluminum magnet wire:
• Aluminum is traditionally 1/3 the cost of copper
• Aluminum is 1/8 the weight of copper
• Aluminum is 1/2 the equal conductive weight of copper
• Aluminum is 1/4 the equal conductive cost of copper

During the same time span (January 1, 2010 through March 31, 2011) copper rocketed to above 10,000 USD/ton, before it dropped to around 9,500 USD/ton.

Table 1: Parameters for testing redesigned IDC terminals to aluminum wire.

<table>
<thead>
<tr>
<th>Group</th>
<th>Wire size</th>
<th>Beam design</th>
<th>Plating</th>
<th>Strain relief</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>6 #21 AWG</td>
<td>Al</td>
<td>Standard</td>
<td>Tin</td>
</tr>
<tr>
<td>2</td>
<td>6 #21 AWG</td>
<td>More Compliant</td>
<td>Beam</td>
<td>Indium Enhanced</td>
</tr>
<tr>
<td>3</td>
<td>6 #21 AWG</td>
<td>Standard Beam</td>
<td>Indium</td>
<td>Enhanced</td>
</tr>
<tr>
<td>4</td>
<td>4 #21 AWG</td>
<td>Al</td>
<td>More Compliant</td>
<td>Standard</td>
</tr>
<tr>
<td>5</td>
<td>4 #21 AWG</td>
<td>Al</td>
<td>More Compliant</td>
<td>Enhanced</td>
</tr>
<tr>
<td>6</td>
<td>4 #21 AWG</td>
<td>Al</td>
<td>More Compliant</td>
<td>Enhanced</td>
</tr>
</tbody>
</table>

Table 2: Comparison of initial T-rise, temperature cycling and humidity cycling.

<table>
<thead>
<tr>
<th>Condition</th>
<th>Test 1</th>
<th>Test 2</th>
<th>Test 3</th>
<th>Test 4</th>
<th>Test 5</th>
<th>Test 6</th>
<th>Test 7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial</td>
<td>5.877</td>
<td>5.874</td>
<td>5.887</td>
<td>5.886</td>
<td>5.932</td>
<td>5.918</td>
<td>5.92</td>
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<tr>
<td>Thermal</td>
<td>5.893</td>
<td>5.887</td>
<td>5.906</td>
<td>5.918</td>
<td>5.958</td>
<td>5.974</td>
<td>5.963</td>
</tr>
</tbody>
</table>

Figure 1: Example for testing leads of standard MAG-MATE terminals to aluminum wire.

Figure 2: Example for testing leads of standard and modified MAG-MATE terminals to aluminum wire.

For more information, visit te.com/products/magnet-wire