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# FIA-IAN-002

## Infrastructure Advisory Note

# THE IMPACT OF COPPER CLAD ALUMINIUM (AND STEEL) CONDUCTORS WITHIN BALANCED PAIR CABLES (INTENDED FOR USE WITHIN IMPLEMENTATIONS OF GENERIC CABLING)

This Infrastructure Advisory Note has not yet been agreed for publication by the TIA-B - the intended distribution vehicle. The FIA (a co-host of the TIA-B) is issuing this draft as a pre-publication document (as an FIA White Paper, available to all) because other industry groups are interested in publishing it and a stable document is required for their consideration.

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# 1 Introduction

The terms Category 5 or Category 5e has become synonymous with “entry level” 4-pair balanced cables. Many users and installers have an ambivalent view of what constitutes these cables. As a result, there is significant pressure on pricing which has encouraged the importation of lower cost products in order to boost supply chain margins or to reduce the capital expenditure of users

This Infrastructure Advisory Note reviews the implications of one specific implementation of these low cost products that claim to be “Category 5” or “Category 5e” using Copper Clad Aluminium (CCA) conductors. This document supports many others prepared by suppliers and trade associations around the world.

NOTE: the most general of these is the joint press release of March 2011 by the US Communications Cable and Connectivity Association (CCCA), www.cccassoc.org, and the Copper Development Association (CDA) which “warns of non-compliant Category cable made with Copper Clad Aluminum conductors”. Members include Accu-Tech; AlphaGary; Anixter; Belden; Berk-Tek, a Nexans Company; Cable Components Group; CommScope; Daikin America; DuPont; 3M; General Cable; Optical Cable Corporation (OCC); OFS, a Furukawa Company; PolyOne; Sentinel Connector Systems; Solvay Solexis; Superior Essex; Tyco Electronics

Cables containing CCA conductors masquerade as standards-compliant “Category 5” or “Category 5e” products - tempting users to specify them and installers to use them.

However, they do not comply with any recognised cable standard in the North America, international or European arenas.

More worryingly, from a contractual, and therefore potentially financial, sense - when used in generic, structured, cabling systems in accordance with the various premises-specific versions of ANSI/TIA-568-C, ISO/IEC 11801 or BS EN 50173 standards - they may:

- fail basic transmission performance tests during commissioning acceptance tests;
- exhibit poor flexibility leading to failed connections during both installation and operation;
- produce higher than expected temperature rises when used to provide power using applications such as Power over Ethernet (PoE and PoE*plus*);
- exhibit oxidation of exposed aluminium at points of connection which may reduce lifetime of those connections, particularly when they are subject to vibration or other movement.

For these reasons, the Fibreoptic Industry Association caution against the use of cables containing CCA conductors within installations where they replace standards-compliant cables of a specified Category.

Furthermore, the Fibreoptic Industry Association caution against the use of cables containing CCA conductors as an alternative to cables of a specified Category (i.e. where the term is not explicitly used but is implicitly indicated as the intended utilisation of the cable).

# 2 Abbreviations

| | | |
|---|---|---|
| ANSI | American National Standards Institute | www.ansi.org |
| AWG | American Wire Gauge | |
| CCA | copper clad aluminium | |
| CENELEC | European Committee for Electrotechnical Standardization | www.cenelec.eu |
| IEEE | | www.ieee.org |
| IEC | International Electrotechnical Committee | www.iec.ch |
| ISO | International Standards Organisation | |
| ISO/IEC | | www.standardsinfo.net |
| PoE | Power over Ethernet | |
| TIA | Telecommunications Industry Association | www.tiaonline.org |

## 3 Cabling and cable standards

Balanced cable “Categories” are defined in three separate sets of regional standards: North American ANSI/TIA-568-C.2, international ISO/IEC 11801 and BS EN 50173-1. While these three standards represent the source of the specification of cable Categories, the Category system is referred to by many other ANSI/TIA, ISO/IEC and European standards and those of other bodies such as IEEE.

In the North American standards, Category 5e defines a cable performance, a connecting hardware performance and an installed cabling performance requirement. In order to produce a Category 5e installed cabling system it is necessary to use Category 5e components.

NOTE: an equivalent approach exists for the delivery of Category 6 and 6A cabling using Category 6 and 6A components.

In the international and European standards, installed cabling is required to meet a transmission performance Class constituting a mix of individual transmission parameters. One way of meeting the required transmission performance Class, called the “reference implementation approach” is to use components of a given Category (there are other methods of conformance, but most installers will adopt this “reference implementation approach”) as follows:

- Class D installed performance - Category 5 components;
- Class E installed performance - Category 6 components;
- Class $E_A$ installed performance - Category $6_A$ components;
- Class F installed performance - Category 7 components;
- Class $F_A$ installed performance - Category $7_A$ components.

There are small differences in performance between Category 5 and 5e (and between the other similarly named Categories in North America and international standardisation) but these differences are relatively unimportant when compared to the potential problems caused by CCA conductors claiming to meet a given Category,

Naturally in order for any of the standards to be viable, the specification of components has to be well defined in order that the overall installation meets the desired level of performance. ANSI/TIA and CENELEC (providing European and British standards) reference their own cable standards whereas ISO/IEC adopt cable standards produced by IEC.

The relevant specifications are shown in the Table 1 below.

| Category | Application | Type | North America | Europe | International |
|---|---|---|---|---|---|
| Category 5 | Distribution | Unscreened | | EN 50288-3-1 | IEC 61156-5 |
| | | Screened | | EN 50288-2-1 | |
| | Flexible | Unscreened | | EN 50288-3-2 | IEC 61156-6 |
| | | Screened | | EN 50288-2-2 | |
| Category 5e | Distribution | Unscreened | ANSI/TIA-568-C.2 | | |
| | | Screened | | | |
| | Flexible | Unscreened | | | |
| | | Screened | | | |
| Category 6 | Distribution | Unscreened | | EN 50288-6-1 | IEC 61156-5 |
| | | Screened | | EN 50288-5-1 | |
| | Flexible | Unscreened | | EN 50288-6-2 | IEC 61156-6 |
| | | Screened | | EN 50288-5-2 | |
| Category 6A/$6_A$ | Distribution | Unscreened | | EN 50288-11-1* | IEC 61156-5 |
| | | Screened | | EN 50288-10-1* | |
| | Flexible | Unscreened | | EN 50288-11-2* | IEC 61156-6 |
| | | Screened | | EN 50288-10-2* | |
| Category 7 | Distribution | Screened | | EN 50288-4-1 | IEC 61156-5 |
| | Flexible | Screened | | EN 50288-4-2 | |
| Category $7_A$ | Distribution | Screened | | EN 50288-9-1* | IEC 61156-6 |
| | Flexible | Screened | | EN 50288-9-2* | |

* standards in development (August 2011)

**Table 1 - Cable specifications**

The cable specifications are divided into application and type. The application of the cable is described in Table 1 as either distribution or flexible. The concept of a distribution cable is best described as a fixed cable with solid, non-stranded, conductors used to connect panels and outlets. The term flexible is sometimes misunderstood assuming that it means cable for use in the creation of cords and using stranded conductors. This is not strictly true since flexible cables can be created using either stranded or non-stranded conductors. However, cables constructed using stranded conductors will tend to exhibit higher resistance and signal attenuation and this is of relevance to this IAN. Therefore, for purposes of simplicity, we will assume that all flexible cable specifications relate to stranded conductors only.

## 4 Conductor construction and cable standards

All the cable specifications detailed in Table 1 require the conductors to be of solid copper (whether or not they are stranded).

Specifically:

- ANSI/TIA-568-C.2 by reference to ANSI/ICEA S-90-661-2006 for Category 5e states that “solid conductors shall consist of commercial pure, annealed, bare copper …” and that, where used “tin coated conductors shall consist of commercially pure, solid annealed copper, tin coated …”;
- IEC 61156 standards state that “the conductor shall be a solid annealed copper conductor”;
- EN 50288 standards state that “the conductor shall be solid copper and comply with the requirements of EN 50288-1:2003” and “the conductor shall be plain or metal coated” (the latter referring to the use tinned copper). In fact the latest EN documents in development (marked with an asterisk in Table 1) go even further by including the additional text shown in red “the conductor shall be annealed solid copper and comply with the requirements of EN 50288-1:2003, 4.1. The conductor shall be plain or metal coated.
  NOTE Copper covered (clad) aluminium and/or steel conductors are not permitted.”

It is therefore very obvious that a conductor that is not solid copper (whether or not tinned) cannot be used within a cable that claims to conform to a Category to North American, international or European standards.

## 5 Copper clad aluminium (CCA) conductors

CCA conductors generally feature a central core of between 60 % and 80 % of the conductor diameter of aluminium with the remaining 40% - 20 % being a copper cladding surrounding the aluminium.

Most of the conventional applications of CCA (such as coaxial cables) use the aluminium to reduce the weight and cost of the cable. The aluminium is a less efficient conductor than copper, but the higher frequencies associated with data transmission are carried within the copper cladding - acting as the “skin” of the conductor. In such cases the transmission performance is provided by the copper, ignoring the aluminium carrier beneath its surface.

In theory, this should provide a CCA-based balanced pair cable with the high frequency performance of a given Category at a lower cost. However, it is not high frequency performance that causes the principal problem and the use of aluminium degrades the performance of the solid copper solution of Category 5/5e cables.

The published IEC and EN cable standards of Table 1 allow conductor diameters between 0,4 mm and 0,8 mm.
NOTE: The EN standards under development (marked with an asterisk in Table 1) do not allow diameters below 0,5 mm.

However, the cabling standards point out that any diameters outside the range 0,5 mm to 0,65 mm are not suitable for installation into “sockets” (i.e. the distribution cables of Table 1). In all cases, the maximum dc resistance allowed for a 100 m conductor is 9,5 Ω.

The North American standards specify a minimum conductor diameter of 0,51 mm (24 AWG) and a maximum dc resistance of 9.38 Ω.

The resistivity of annealed copper is $1{,}72 \times 10^{-8}$ whereas the resistivity of aluminium is $2{,}82 \times 10^{-8}$. The resistance of an aluminium conductor is therefore 64% above that of copper conductor of equal cross-sectional area. The production of a composite CCA conductor produces conductors that have resistance approximately 40% above the copper equivalent.

## 6 Transmission performance failures during acceptance testing

Installers are rarely going to attempt to confirm the performance of a cable against a standard at component level. Any problems of transmission performance will only come to light following termination of the cables - and when acceptance testing is being undertaken.

The obvious difference between copper and CCA conductors is DC resistance.

DC loop resistance is a requirement for compliance with the:

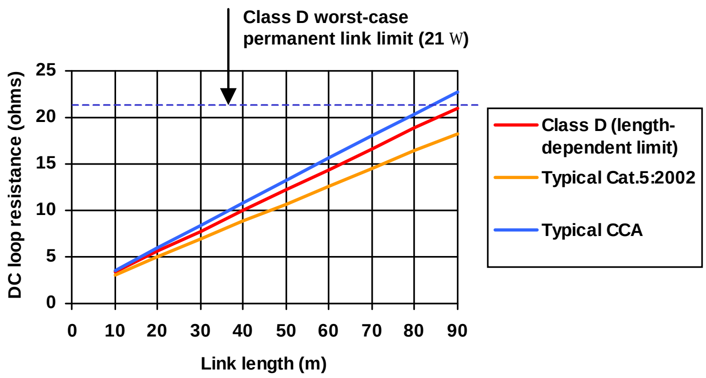
§ Category 5e, 6 or 6A requirements of permanent links and channels in accordance with ANSI/TIA-568-C.2;

§ Class D, E, $E_A$, F and $F_A$ requirements of permanent links and channels in accordance with both ISO/IEC 11801 and EN 50173-1.

In both cases the limits are the same i.e. 25 Ω for channels, 21 Ω for worst-case permanent links. The 21 Ω limit contains some margin for thermal effects caused by transmitted current since, at 20 $^{o}$C, 90 metres of Category 5 cable and three connections delvers a loop resistance of 19.6 Ω).

NOTE: DC loop resistance is twice the DC resistance of a conductor

If the resistance of CCA conductors is 40% above that of solid copper, permanent links can be expected to be non-compliant for lengths in excess of approximately 80 metres. If the resistance premium of the CCA conductor is higher or lower than 40%, the distance at which non-compliance occurs will be shorter or longer respectively.




However, this is not the whole story. Basic compliance with the requirements of ISO/IEC 11801 and BS EN 50173 standards requires channels to conform to the relevant limits.

However, for DC loop resistance some consideration has to be given to the effect of channel length because when the cable is used for power feeding all the assumptions about cable heating are based upon a given power dissipation per meter. Clearly, if all 25 Ω were concentrated in a 1 m length, the heating effect would be massively greater than predicted by the models used by the standards bodies.

To some extent this problem is resolved by testing permanent links against the true Class requirements of both ISO/IEC 11801 and EN 50173-1 as these requirements are length-based on the assumption of 0,22 Ω per metre for the cable plus connections.

As can be seen in the figure, all lengths of CCA cabling would fail, to varying degrees, when assessed against the detailed requirements of theses standards.. However, most test equipment does not assess against length-based calculated limits.

Unfortunately, compliance with the requirements of Category 5e, 6 or 6A requirements of permanent links do not require this type of length-dependency. This is compounded by the fact that test equipment in accordance with ANSI/TIA-1152, used to assess compliance with requirements of Category 5e, 6 or 6A requirements of permanent links and channels in accordance with ANSI/TIA-568-C.2, is only required to provide information about DC resistance result i.e. not indicating a FAIL condition - even though conformance to cabling standard demands compliance with the relevant limits.

NOTE: This apparent paradox can result is a non-compliant channel or permanent link (in terms of DC resistance) going unnoticed. To avoid problems resulting from any subsequent oversight, the exact implementation of result presentation needs to be checked with the test equipment supplier.

However, testing against the requirements of permanent links and channels in accordance with both ISO/IEC 11801 and EN 50173-1 will automatically register a “FAIL” result if the limits are breached.

The AC transmission parameters of the balanced cables are also affected. Insertion loss/attenuation is also likely to be flagged under similar conditions as for DC loop resistance – particularly at lower frequencies.

There are other factors which can affect the intra- and inter-pair noise parameters such as return loss, NEXT and ACR-F respectively. The comparative lack of physical strength of the conductor makes it more difficult maintain impedance control during the production process and also results in misalignment of conductors within the cable construction. These effects are not dependent upon installed length and may be exacerbated during and following installation.

## 7 Power over Ethernet and other power distribution applications

The latest standard for Power over Ethernet IEEE 802.3at (sometimes termed PoE*plus*) increased the current per conductor to 300 mA, based upon advice from the standards bodies responsible for ANSI/TIA-568-C.2 and ISO/IEC 11801.

Clearly if the resistance of those conductors is increased as is the case with CCA implementations, the thermal impact is greater. This exacerbates a concern already being expressed about the use of balanced cables to support currents in excess of these figures.

CCA **will** overheat, and quite quickly. For a given applied current, initial temperature increases can be twice those seen on a solid copper conductor. When the cable does start to overheat a vicious spiral begins and unless the current is switched off there is no going back to a point of safe working. This could cause extensive damage to the cable and adjacent cables.

If cords contain stranded CCA conductors, the impact on heating is further emphasised.

## 8 The impact of flexing and bending

Aluminium has a poor malleability compared to copper; meaning that it will break easily if overworked.

Although distribution cables are generally fixed in position, there are situations where they are subject to intermittent but substantial movement. Examples of such situations include where distribution cables are fed to untethered sub-floor boxes and where distribution cables are installed between those floor boxes and furniture-based outlets. The flexing that such cables undergo may result in cracked conductors - particularly if the areas subjected to flexing are also linked to areas of oxidation as described in clause 9.

Table 1 contains a list of specifications for flexible cables intended for the production of cords (typically work area cords, patch cords and equipment cords). The enhanced requirements for flexibility demanded by those specifications, whether or not stranded conductors are used, are difficult (if not impossible) for CCA cables to meet.

## 9 The impact of oxidation

Aluminium starts to oxidize as soon as it is exposed to the air - such as when insulation displacement connections are employed to terminate the conductor - either in plug or socket connections. The contact performance of the oxidised area will quickly deteriorate causing hot spots. The mechanical performance of the oxidised area will also be affected which can cause the CCA to snap off when subject to vibration or minor displacement. Repair of such defects frequently requires the movement of adjacent terminations resulting in further damage in a “pack-of-cards” sequence.

The operational downtime can become prohibitive for the user - and maintaining these installations can be very costly for an installer.

## 10 Commercial implications of using CCA cables

Installers should not supply CCA cables against contracts that demand:

- Category-based performance for the cable against North American, international or European standards;
- that the installed cabling meets a given Category against ANSI/TIA-568-C.2;
- that the installed cabling meets a given Class against ISO/IEC 11801 or EN 50173-1 (without a significant risk of failure during acceptance testing).

If a user specifies the use of CCA cables then they cannot simultaneously demand Category-based performance for the cable against North American, international or European standards.

If a user specifies the use of CCA cables then they cannot simultaneously request that the installed cabling meets a given Category against ANSI/TIA-568-C.2.

If a user specifies the use of CCA cables then they cannot simultaneously demand Category-based performance for the cable or request that the installed cabling meets a given Class against ISO/IEC 11801 or EN 50173-1 without a significant risk of failure during acceptance testing.

If a user specifies the use of CCA cables then the installer needs to formally advise the user that the installation should not be used to support Power over Ethernet or other power supplies due to the probable excessive heating that may result.

If a user is unaware of the use of CCA cables within an installation, it is very probable that they will find out due to the significant quantity of failures during acceptance testing.  This could result in demands for replacement of the entire installation and/or litigation on the basis of breach of contract.

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| | |
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| ANSI/TIA-1152 | *Requirements for Field Test Instruments and Measurements for Balanced Twisted-Pair Cabling* |
| ANSI/ICEA S-90-661-2006 | *Category 3, 5, & 5e Individually Unshielded Twisted Pair Indoor Cables (With or Without an Overall Shield) for Use in General Purpose and LAN Communication Wiring Systems Technical Requirements, 2006* |
| BS EN 50173-1 | *Information technology - Generic cabling systems - Part 1: General requirements* |
| EN 50288-1 | *Multi-element metallic cables used in analogue and digital communication and control – Part 1: Generic specification* |
| EN 50288-2-1 | *Multi-element metallic cables used in analogue and digital communication and control - Part 2-1: Sectional specification for screened cables characterized up to 100 MHz - Horizontal and building backbone cables* |
| EN 50288-2-2 | *Multi-element metallic cables used in analogue and digital communication and control - Part 2-2: Sectional specification for screened cables characterised up to 100 MHz - Work area and patch cord cables* |
| EN 50288-3-1 | *Multi-element metallic cables used in analogue and digital communication and control - Part 3-1: Sectional specification for unscreened cables characterised up to 100 MHz - Horizontal and building backbone cables* |
| EN 50288-3-2 | *Multi-element metallic cables used in analogue and digital communication and control - Part 3-2: Sectional specification for unscreened cables characterised up to 100 MHz - Work area and patch cord cables* |
| EN 50288-4-1 | *Multi-element metallic cables used in analogue and digital communication and control - Part 4-1: Sectional specification for screened cables characterised up to 600 MHz - Horizontal and building backbone cables* |
| EN 50288-4-2 | *Multi-element metallic cables used in analogue and digital communication and control - Part 4-2: Sectional specification for screened cables characterised up to 600 MHz - Work area and patch cord cables* |
| EN 50288-5-1 | *Multi-element metallic cables used in analogue and digital communication and control - Part 5-1: Sectional specification for screened cables characterized up to 250 MHz - Horizontal and building backbone cables* |
| EN 50288-5-2 | *Multi-element metallic cables used in analogue and digital communication and control - Part 5-2: Sectional specification for screened cables characterized up to 250 MHz - Work area and patch cord cables* |
| EN 50288-6-1 | *Multi-element metallic cables used in analogue and digital communication and control - Part 6-1: Sectional specification for unscreened cables characterised up to 250 MHz - Horizontal and building backbone cables* |
| EN 50288-6-2 | *Multi-element metallic cables used in analogue and digital communication and control - Part 6-2: Sectional specification for unscreened cables characterised up to 250 MHz - Work area and patch cord cables* |
| EN 50288-9-1 | *Multi-element metallic cables used in analogue and digital communications and control - Part 9-1: Sectional specification for screened cables characterised up to 1 000 MHz - Horizontal and building backbone cables* |
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| | *Part 11-2: Sectional specification for un-screened cables, characterised up to 500 MHz - Work area and patch cord cables* |
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| IEC 61156-6 | *Multicore and symmetrical pair/quad cables for digital communications - Part 6: Symmetrical pair/quad cables with transmission characteristics up to 1 000 MHz - Work area wiring - Sectional specification* |
| ISO/IEC 11801 | *Information technology - Generic cabling for customer premises* |