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TECHNICAL SPECIFICATION

colour inside

Information technology – Telecommunications cabling requirements for remote powering of terminal equipment

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FOREWORD

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- when the subject is still under technical development or where, for any other reason, there is the future but not immediate possibility of an agreement on an International Standard.

Technical Specifications are subject to review within three years of publication to decide whether they can be transformed into International Standards.

ISO/IEC TS 29125, which is a Technical Specification, has been prepared by subcommittee 25: Interconnection of information technology equipment, of ISO/IEC joint technical committee 1: Information technology.

This first edition cancels and replaces ISO/IEC TR 29125:2010. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

a) extension of the current per conductor from 300 mA to 500 mA;
b) provision of additional details of installation conditions that were not described in ISO/IEC TR 29125:2010;
c) inclusion of guidelines for cords;
d) inclusion of a model to calculate temperature rise in different bundle sizes.

This Technical Specification has been approved by vote of the member bodies, and the voting results may be obtained from the address given on the second title page.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

IMPORTANT – The 'colour inside' logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

INTRODUCTION

This document specifies the use of generic balanced cabling for customer premises, as specified in the ISO/IEC 11801 series, for remote powering of terminal equipment. It provides guidance on new cabling installations and renovations. The customer premises may encompass one or more buildings or may be within a building that contains more than one organization. The cabling may be installed prior to the selection of remote powering equipment or powered terminal equipment.

ISO/IEC 11801-1 specifies a structure and performance requirements for cabling subsystems that support a wide range of applications. They provide appropriate equipment interfaces to the cabling infrastructure in equipment rooms, telecommunications rooms and work areas.

A growing number of organizations employ equipment at locations that require the provision of remote powering. This document was created to provide supplementary information to ISO/IEC 11801-1 to implement remote powering over generic balanced cabling as specified in ISO/IEC 11801-1.

This document provides additional guidance for remote powering on the use of balanced cabling systems as specified in ISO/IEC 11801-1 and guidance on different installation conditions that require special considerations:

- information to bring together all the considerations about remote powering in a single document;
- guidance on mating and un-mating of connectors that convey remote power.

This document does not include requirements from national or local safety standards and regulations.

This document was developed based on a number of contributions describing remote powering over telecommunications cabling under different installation conditions. The relevant safety standards and regulations, application standard, and equipment manufacturers give guidance on factors that should be taken into account during design of the generic balanced cabling that supports the distribution of remote powering.

This document extends the current per conductor specified in ISO/IEC TR 29125:2010 from 300 mA to 500 mA. This document covers additional details of installation conditions that are not described in ISO/IEC TR 29125:2010. This document includes guidelines for cords.

INFORMATION TECHNOLOGY –

TELECOMMUNICATIONS CABLING REQUIREMENTS FOR REMOTE POWERING OF TERMINAL EQUIPMENT

1 Scope

This document

a) addresses the support of safety extra low voltage (SELV) and limited power source (LPS) applications that provide remote power over balanced cabling in accordance with the reference implementations of ISO/IEC 11801 series standards using currents per conductor of up to 500 mA and targets the support of applications that provide remote power over balanced cabling to terminal equipment,

b) covers the transmission and electrical parameters needed to support remote power over balanced cabling,

c) covers various installation scenarios and how these may impact the capability of balanced cabling to support remote powering,

d) specifies design and configuration of cabling as specified in ISO/IEC 11801-1.

NOTE SELV requirements specify a maximum voltage of 60 V DC and LPS is understood in the applications referenced to be up to 100 W supplied within 4-pair cabling.

This document includes a mathematical model to predict the behaviour of different bundle sizes, various cabling constructions, and installation conditions for different current capacities.

Safety (e.g. electrical safety and protection and fire) and electromagnetic compatibility (EMC) requirements are outside the scope of this document, and are covered by other standards and regulations. However, information given by this document can be of assistance.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO/IEC 11801-1, *Information technology – Generic cabling for customer premises – Part 1: General requirements*

ISO/IEC 14763-2, *Information technology – Implementation and operation of customer premises cabling – Part 2: Planning and installation*

ISO/IEC TR 24746, *Information technology – Generic cabling for customer premises – Mid-span DTE power insertion*

3 Terms, definitions and abbreviated terms

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO/IEC 11801-1, ISO/IEC 14763-2 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

3.1.1
power source equipment
equipment that provides power

3.1.2
cable bundle
several cables tied together or in contact with one another in a parallel configuration for at least 1 m, with the cross-section profile of the arrangement basically circular

3.1.3
conductor
element intended to carry electric current

[SOURCE IEC 60050-151:2001, 151-12-05, modified – The 3 Notes have been deleted.]

3.1.4
current carrying capacity
maximum current a cable circuit (one or several conductors) can support resulting in a specified increase of temperature of the conductor beyond the ambient temperature, not exceeding the maximum allowed operating temperature of the cable

[SOURCE: IEC 61156-1:2007/AMD1:2009, 3.24, modified – "increase of temperature" has replaced "increase of the surface temperature".]

3.1.5
remote powering
supply of power to application specific equipment via balanced cabling

3.1.6
temperature rise
difference in temperature between the initial temperature of the conductor without power and the final temperature of the powered conductor at steady state

3.2 Abbreviated terms

EMC electromagnetic compatibility

FD floor distributor

HVAC heating, ventilation and air conditioning

PTZ pan, tilt, zoom

WAP wireless access point

4 Conformance

For cabling to comply with this document, the following applies:

a) the design of the cabling shall comply with the relevant cabling design standard of the ISO/IEC 11801 series;

b) the installation shall comply with ISO/IEC 14763-2 as amended by the additional requirements of this document.

5 Cabling selection and performance

Cabling for remote powering should be implemented using 4-pair balanced cabling.

This cabling will be used simultaneously to support signal transmission and remote power feeding for the terminal equipment. This document assumes the use of balanced cabling components specified in the reference implementation clause of the relevant design standards of the ISO/IEC 11801 series.

The transmission parameters of balanced cables related to remote powering can be found in Annex C.

6 Installation conditions

6.1 General

Cabling may be installed in different types of continuous and non-continuous pathway systems as described in ISO/IEC 14763-2. The installation of a cable within the pathway systems should take into account the specified operating temperature of the cable. Due to the Joule effect, each energized conductor has a temperature rise. Larger cable bundles have more heat generation and therefore the temperature rise is worse than smaller cable bundles.

The cable bundle size is limited by the current capacity in 6.3 and the induced temperature rise that results in an operating temperature of the cable, not to exceed its temperature rating.

The following guidelines for pathway selection and installation should be considered:

a) installation design including the type of pathways selected, the pathway fill factor, whether the pathway is sealed at both ends,

b) the pathway environment and whether the pathway goes through thermally insulated areas, in which case the type of insulation will be a significant factor. For optimal thermal performance, pathway design should avoid any insulated areas,

c) thermal aspects of the entire pathway (e.g. open tray, closed tray, ventilated, non-ventilated, plastic conduit, metal conduit, fire barriers) should be taken into account.

6.2 Ambient temperature

Different segments of a link can have different ambient temperatures, which can influence the amount of remote power that can be delivered. Therefore the ambient temperature in different length segments of a link or channel has a direct impact on the operating temperature of the cable used for the link or channel and can limit the capability of the cable for remote power delivery to powered terminal equipment. The worst case installed cabling condition with respect to the maximum ambient temperature shall be used to determine the maximum operating temperature for a link or channel when subject to remote powering.

6.3 Temperature rise and current capacity

When remote power is applied to balanced cabling, the temperature of the cabling will rise due to resistive heat generation (Joule effect) in the conductors. Depending on cable construction and installed cabling conditions, the heat generated will be dissipated into the surrounding environment until a steady state is reached with the temperature of the cable bundle (operating temperature) higher than the ambient temperature of the surrounding environment. The maximum temperature of any cable shall not exceed the temperature rating of the cable. The standards in the ISO/IEC 11801 series require this temperature to be 60 °C (minimum).

Temperature rise in the cable will lead to an increase in insertion loss as indicated in the reference implementations of the ISO/IEC 11801 series standards and should be taken into account when selecting cables and using them in links or channels. The maximum length of the channel or link should be reduced based on the maximum temperature of the cable using the de-rating factors in ISO/IEC 11801-1.

The maximum current per conductor for different temperature rise in a bundle of 37 cables of 4-pair Category 5 cables with solid conductors, and 37 cords of 4-pair 0,40 mm stranded cords with all pairs energized is shown in Table 1.

Annex B provides an engineering model that may be used for specific cable types, cable constructions, and installation conditions to derive the bundle size for a particular current per conductor. Clause B.7 describes a simplified version of the engineering model in Annex B and was used to derive the worst case values in Tables 1, 2, 3 and 4 based on constants calculated from measurements of typical cables for each cable category. The measurement procedures used to determine the constants are detailed in Annex F.

Table 1 – Maximum current per conductor versus temperature rise in a 37-cable bundle in air and conduit (all 4 pairs energized)

Temperature rise °C	Current per conductor 0,4 mm cords mA		Current per conductor Category 5 cables mA	
	air	**conduit**	**air**	**conduit**
5	278	223	341	287
7,5	340	273	418	351
10	393	315	482	406
12,5	439	352	539	453
15	481	386	591	497
17,5	520	417	638	537
20	556	446	682	574
Temperature rise above 10 °C shown in grey background is not recommended.				
NOTE These values are based on conductor temperature measurement of typical cables and cords.				

Table 2 shows current capacity for different categories of cable, independent of construction, for a given temperature rise.

Table 2 – Calculated worst case current per conductor versus temperature rise in a bundle of 37 4-pair cables (all pairs energized)

ΔT	0,4 mm cords mA		Category 5 cables mA		Category 6 cables mA		Category 6_A cables mA		Category 7 cables mA		Category 7_A cables mA	
°C	air	cond-uit	air	cond-uit	air	cond-uit	air	cond-uit	air	cond-uit	air	cond-uit
2	175	141	215	181	246	207	267	229	267	229	324	264
4	248	199	305	256	348	293	378	324	378	324	459	373
6	304	244	373	314	427	359	463	397	463	397	562	457
8	351	282	431	363	493	414	535	459	535	459	649	528
10	393	315	482	406	551	463	598	513	598	513	725	590
12	430	345	528	444	604	507	655	562	655	562	795	646
14	465	373	571	480	652	548	708	607	708	607	858	698
16	497	399	610	513	697	586	756	649	756	649	918	746
18	527	423	647	544	740	622	802	688	802	688	973	792
20	556	446	682	574	780	655	846	725	846	725	1026	835

Temperature rise above 10 °C shown in grey background is not recommended.

The values in this table are based on the implicit DC resistance derived from the insertion loss of the various categories of cable. Manufacturers' and/or suppliers' specifications give information relating to a specific cable.

NOTE The current per conductor for each category is dependent on the cable construction.

6.4 Factors affecting temperature increase

6.4.1 General

The steady state temperature for the conductor of any power carrying cable is reached when the generation of heat within the cable (Joule effect) is equal to the heat dissipated into the environment, be it the open atmosphere, trays, ducts or other cables which can also be power carrying cables.

6.4.2 Installation near equipment

Ambient temperature near equipment will be higher and also installation of telecommunications cables and cords in hot aisles will lead to higher ambient temperature around the patch cord bundle.

6.4.3 Cable count within a bundle

This document uses 37-cable bundles as the basis for developing the temperature rise and current per conductor with all pairs energized. For other cases (e.g. where bundle count exceeds 37 cables), the guidelines provided in 6.4 can be used. Refer to Table 3 to determine the maximum temperature rise using 500 mA per conductor for cable bundles of different count.

Table 3 – Temperature rise versus cable bundle size (500 mA per conductor)

Number of cables	Temperature rise °C											
	0,4 mm cords		Cat 5 cables		Cat 6 cables		Cat 6_A cables		Cat 7 cables		Cat 7_A cables	
	air	cond-uit	air	cond-uit	air	cond-uit	air	cond-uit	air	cond-uit	air	cond-uit
1	1,9	3,1	1,1	1,7	0,8	1,3	0,7	1,1	0,7	1,1	0,6	0,9
7	5,7	9,1	3,5	5,2	2,6	4,0	2,3	3,3	2,3	3,3	1,7	2,6
19	10,5	16,5	6,7	9,7	5,1	7,4	4,4	6,1	4,4	6,1	3,1	4,7
24	12,2	19,1	7,9	11,3	6,0	8,7	5,1	7,1	5,1	7,1	3,6	5,5
37	16,2	25,1	10,7	15,2	8,2	11,6	7,0	9,5	7,0	9,5	4,7	7,2
48	19,3	29,8	13,0	18,2	10,0	14,0	8,5	11,4	8,5	11,4	5,7	8,5
52	20,3	31,4	13,8	19,3	10,6	14,8	9,0	12,0	9,0	12,0	6,0	9,0
61	22,7	34,9	15,5	21,6	12,0	16,6	10,1	13,4	10,1	13,4	6,7	10,0
64	23,5	36,1	16,1	22,4	12,4	17,1	10,5	13,9	10,5	13,9	6,9	10,3
74	26,0	39,8	17,9	24,9	13,9	19,1	11,7	15,4	11,7	15,4	7,7	11,3
91	30,1	45,9	21,0	29,0	16,4	22,2	13,8	17,9	13,8	17,9	8,9	13,1

Temperature rise above 10 °C shown in grey background is not recommended.

The values in this table are based on the implicit DC resistance derived from the insertion loss of the various categories of cable. Manufacturers' and/or suppliers' specifications give information relating to a specific cable.

NOTE 1 The temperature rise (°C) is based upon a current of 500 mA per conductor, for all pairs in all cables in the bundle.

NOTE 2 The current per conductor for each category is dependent on the cable construction.

6.4.4 Reducing temperature increase

Minimizing the cabling temperature rise is recommended, as it

a) reduces the impact on the transmission performance (e.g. insertion loss) of the cabling,

b) reduces the HVAC loading within the premises,

c) allows operation in higher ambient temperatures without exceeding the cable temperature rating,

d) reduces the overall cost of delivering remote power by minimizing the resistive heating loss (power dissipated in the cabling).

The temperature rise can be reduced by minimizing the heat generation and maximizing the heat dissipation. Examples of how this can be achieved include:

– using higher category cable,
– selecting a larger conductor size which decreases per unit length DC resistance,
– improving thermal dissipation by selecting cable with
  • improved heat transfer coefficient between materials within the cable,
  • improved heat transfer coefficient between cable sheath and air,
  • screen or other additional metallic elements,
  • solid insulation,
  • a larger diameter,
– reducing the number of energized pairs,

– reducing the number of cables per bundle and avoiding tight cable bundles,
– selection of applications and devices that use lower current.

NOTE Manufacturers’ and/or suppliers’ specifications give information relating to a specific cable.

Mixing power-carrying cabling with unpowered cabling in bundles is also recommended as a practice to minimize heat rise.

If bundling is necessary, separate large bundles into smaller bundles, as described in Annex D. Other mitigation considerations are described in Annex A. Otherwise avoid bundling cables to minimize temperature rise.

Table 4 shows the effect of energizing the number of pairs within a 37-cable bundle for different cable categories.

The recommendation of ISO/IEC 14763-2 for cable bundles of no more than 24 is further reinforced for remote powering due to:

1) installation factors,
2) possible high ambient temperature,
3) the use of 0,4 mm conductor diameter cords,
4) higher currents up to 500 mA per conductor with all 4 pairs energized.

Table 4 – Temperature rise for a type of cable versus the number of energized pairs in a 37-cable bundle (500 mA per conductor)

No. of pairs	ΔT (°C)											
	0,4 mm cords		Cat 5 cables		Cat 6 cables		Cat 6_A cables		Cat 7 cables		Cat 7_A cables	
	air	cond-uit	air	cond-uit	air	cond-uit	air	cond-uit	air	cond-uit	air	cond-uit
24	5,2	8,4	3,2	4,7	2,4	3,6	2,0	3,0	2,0	3,0	1,5	2,4
48	7,9	12,5	5,0	7,2	3,7	5,5	3,2	4,6	3,2	4,6	2,3	3,6
96	12,2	19,1	7,9	11,3	6,0	8,7	5,1	7,1	5,1	7,1	3,6	5,5
144	15,9	24,7	10,5	14,9	8,0	11,4	6,8	9,3	6,8	9,3	4,7	7,0
148	16,2	25,1	10,7	15,2	8,2	11,6	7,0	9,5	7,0	9,5	4,7	7,2

Temperature rise above 10 °C shown in grey background is not recommended.

The values in this table are based on the implicit DC resistance derived from the insertion loss of the various categories of cable. Manufacturers’ and/or suppliers’ specifications give information relating to a specific cable.

NOTE 1 The temperature rise (°C) is based upon a current of 500 mA on each energized conductor

NOTE 2 The current per conductor for each category is dependent on the cable construction.

6.4.5 Cable bundle suspended in air

The maximum ambient temperature of 50 °C is possible in certain environments and operating conditions. To allow for this ambient temperature and limit the temperature rise to 10 °C, for the minimum Category 5 cables supporting 500 mA per conductor, it is necessary to limit the bundle size to a smaller number than 100 cables.

6.4.6 Administration

The administration system as described in ISO/IEC 14763-2 can be used to select the channels in a bundle to use to supply power optimally. For example, the administration system can be used to record the powering details of the cables used for remote powering. An AIM system as specified in ISO/IEC 18598 can be designed to use bundle records and issue alerts when a bundle exceeds its thermal capacity.

7 Remote power delivery over balanced cabling

Figure 1 shows examples of specified transmission paths used in generic balanced cabling. The channel is the transmission path between equipment such as a LAN switch or hub and the terminal equipment. The channel does not include the connections at the data source equipment and the terminal equipment. The channel, the permanent link or the CP link shall meet the transmission requirements specified in the design standards.

Remote power may be provided to terminal equipment via balanced cabling equipment interfaces. Remote power may be introduced to the balanced cabling channel at the FD using spare pairs, if available, or by remote power supplied over the phantom circuit of data pairs from the power sourcing equipment, as shown in Figure 1.

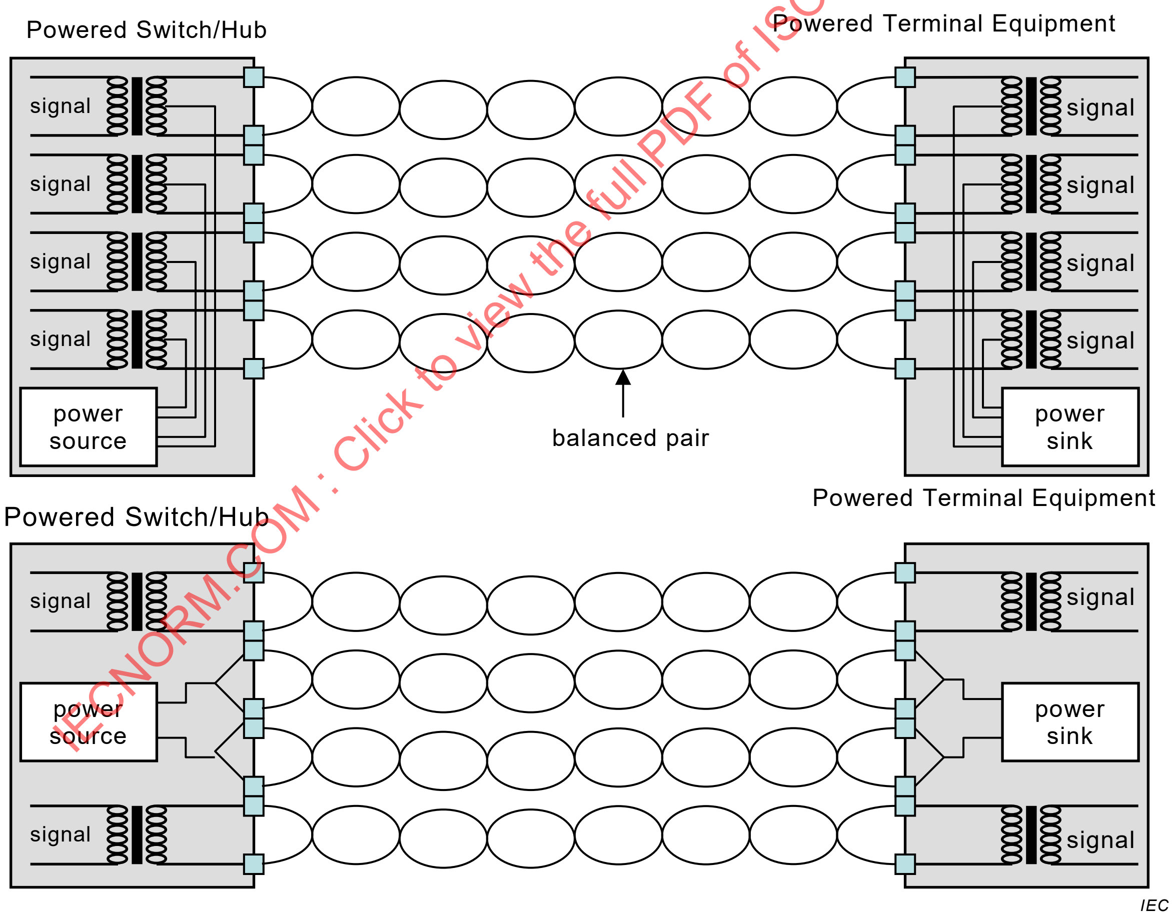

Figure 1 – Examples of end point powering systems using signal pairs (top) and spare pairs (bottom)

Alternatively, remote power may be supplied by mid-span power source equipment that inserts remote power independent of the data source equipment, as shown in Figure 2.

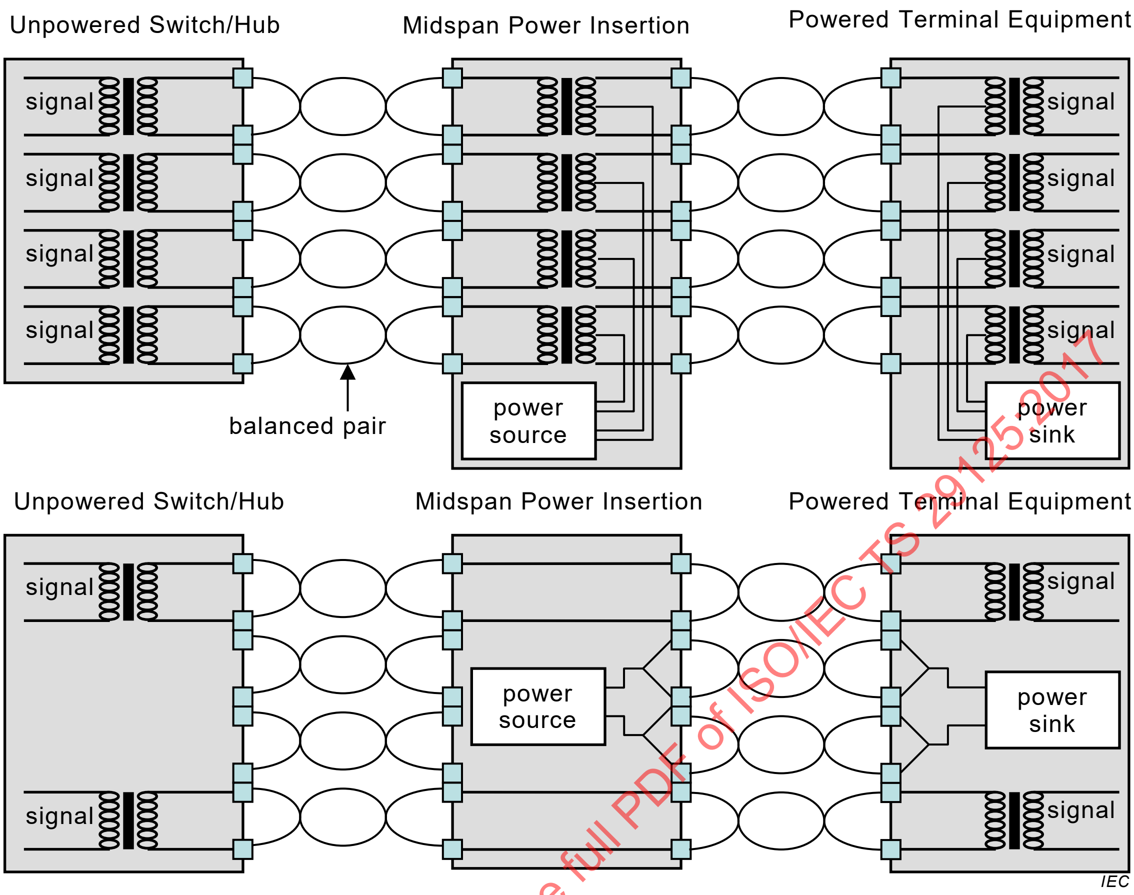

Figure 2 – Examples of mid-span powering systems

When mid-span power source equipment replaces a generic balanced cabling component or components, the data pairs shall meet the performance requirements of the component or components it replaces (e.g. patch cord, patch panel or combination thereof), regardless of the equipment interfaces used for input and output connections. Placement of mid-span power insertion equipment shall be external to the permanent link, see ISO/IEC TR 24746.

8 Connecting hardware

Connecting hardware in channels used to support remote power applications shall have an appropriate current rating when mated. Connecting hardware contacts may deteriorate as a result of mating or un-mating under electrical load, leading to possible degradation of transmission characteristics (see IEC 60512-99-001). Manufacturers should be consulted regarding the number of mating and un-mating cycles supported by connecting hardware while conveying the intended levels of electrical power.

The temporary removal of remote power should be considered before mating or un-mating connecting hardware in a remotely powered channel.

It is preferable that remote powering is not present during mating or un-mating of connecting hardware.

Intelligent powering systems such as Power over Ethernet and Power over Ethernet-*plus* (defined in ISO/IEC/IEEE 8802-3) automatically recognize compliant loads before applying the required level of remote power, thus eliminating electrical stress during connector mating.

ISO/IEC/IEEE 8802-3 also defines optional features to remotely manage the provision of electrical power to each port via port power management which can be used to remove remote power from a particular channel prior to un-mating connectors.

Port power management is therefore the preferred approach to reconfiguration of remotely powered cabling channels.

Where it is not practicable to switch off the remote power before mating or un-mating (e.g. for power sources that do not have power management), connecting hardware having the required performance for mating and un-mating under the relevant levels of electrical power and load should be chosen. These requirements are not within the scope of the balanced connecting hardware standards (e.g. IEC 60603-7, IEC 61076-3-104 and IEC 61076-3-110) referenced from ISO/IEC 11801-1 and equivalent standards but may be assessed using additional test schedules.

NOTE A test schedule for engaging and separating connectors under electrical load is described in IEC 60512-99-001.

Annex A
(informative)

Mitigation considerations for installed cabling

A.1 General

Installed cabling is not easy to change to support new applications with additional requirements. Annex A offers some considerations that can be useful to provide remote power over existing installations of Class D or better balanced cabling. Consideration should be given to local heat dissipation conditions, for instance going through framed wall construction or through insulating material.

A.2 Minimum cabling class

Class D is the minimum cabling suitable for remote powering. Better balanced cabling is recommended to allow higher power needed by emerging applications such as next generation WAPs and outdoor heated PTZ cameras.

A.3 Bundle size and location

Cables with improved thermal characteristics may be configured into larger bundles. The location of a cable bundle is also an important consideration. Conduits sealed at both ends typically retain more heat than open conduits, leading to a higher temperature rise in the sealed conduit. If cables are installed in an open tray, the temperature rise will be lower than the temperature rise in conduits (sealed or unsealed) for the same bundle size.

A.4 Mitigation options

If an existing installation does not meet the current capacity in this document for a particular bundle size, the following mitigation options may be considered.

a) Use only half the cables in a bundle for remote powering with the other half used for applications that do not need remote power.

b) If ambient temperatures are high, consider adding air-conditioning or air-circulation over cabling segments that are exposed to high temperature.

c) If possible, separate larger bundles into smaller bundles.

If it is not possible to implement any of the mitigation options listed above, and the number of data terminals requiring remote powering is significant, upgrade the installation using cables with improved thermal characteristics.

Additionally, when the number of data terminals requiring remote powering is significant, upgrade the installation using the appropriate installation procedures to keep the bundle size reasonably low (e.g. 24 cable count) to allow proper heat dissipation all along the channel, permanent link or CP link.

Annex B
(informative)

Modelling temperature rise for cable types, bundle sizes and installation conditions

B.1 Model basics

This model derives the temperature rise based on measured data for different cable types and installation environments:

a) ΔT is the total temperature rise between the ambient temperature (or that of the unpowered bundle) and the centre of the bundle;

b) ΔT_{th} is the temperature rise between the outer surface and the centre of the bundle;

c) ΔT_{u} is the temperature rise between the ambient temperature (or that of the unpowered bundle) and the outer surface of the bundle.

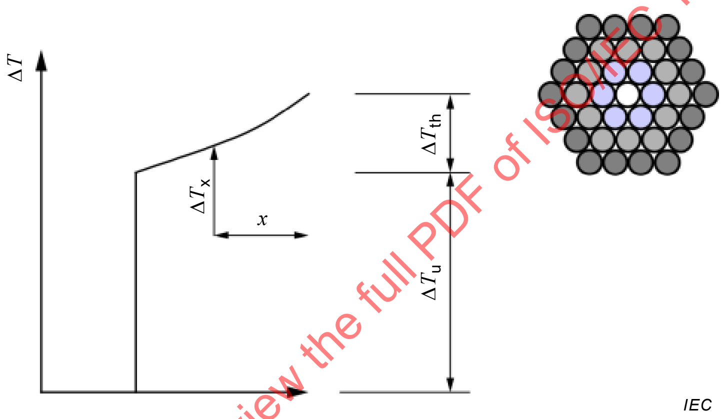

Figure B.1 – Temperature rise profile

An additional element of the model provides a calculation for the temperatures within the bundle at a distance x from the centre (ΔT_x).

B.2 Power dissipated (P)

The model uses a common factor which is defined as P:

$$P = N \times n_c \times i_c^{\,2} \times R \tag{B.1}$$

where

i_c is the current per conductor (A) = 0,5 times the current delivered by a pair;

n_c is the number of conductors per cable carrying remote powering current (i_c)
= 2 times the number of pairs carrying remote powering current;

N is the number of cables carrying remote powering current;

R is the average DC resistance per unit length (Ω/m) of conductors carrying remote powering current.

It is recognized that resistance is a function of temperature. This may be neglected for small temperature rises of ≤ 20 °C. However, for calculations resulting in larger temperature rises iteration should be employed within the model. Without such iteration the model produces an underestimate of the temperature rise.

B.3 Temperature difference from ambient temperature to bundle surface (ΔT_u)

B.3.1 Model equations

$$\Delta T_u = \frac{\rho_u \times P}{\left(d \times \sqrt{N} \times \sqrt[4]{\frac{3}{4} \times \pi^6}\right)} \approx \frac{\rho_u \times P}{\left(d \times \sqrt{N} \times 5{,}182\right)} \ ^\circ\text{C} \qquad \text{(B.2)}$$

where

ρ_u is the constant relating to installation environment;

d is the cable diameter (m).

B.3.2 Typical values for constant ρ_u

Examples of factors for common use cases determined empirically are listed below. Other use cases may be developed under engineering supervision. Formula (B.2) indicates that for all cable constructions and conduits/trays filled up to at least 40 % capacity as defined in ISO/IEC 14763-2, ρ_u is

a) 0,15 under ventilated conditions,

b) 0,25 for plastic conduits or open metal trays,

c) 0,5 for closed metal trays,

d) 0,75 with insulation.

The mapping of test results is ongoing and may lead to a refinement of these models.

B.4 Temperature difference from bundle surface to bundle centre (ΔT_{th})

B.4.1 Model equations

$$\Delta T_{th} = \frac{\rho_{th} \times P}{4 \times \pi} \approx \frac{\rho_{th} \times P}{12{,}6} \ ^\circ\text{C} \qquad \text{(B.3)}$$

where

ρ_{th} is a constant relating to cable construction.

B.4.2 Typical values for constant ρ_{th}

Work undertaken during the development of this document and mapping of test results to the model into Formula (B.3) indicates that:

– ρ_{th} = 5 for U/UTP cable constructions;

– ρ_{th} = 3 for F/UTP cable constructions;

– ρ_{th} = 2,75 for S/FTP cable constructions.

The mapping of test results is ongoing and might lead to a refinement of these models.

B.5 Temperature variation within the bundle ($\Delta T(x)$)

The temperature variation within the bundle is calculated according to Formula (B.4):

$$\Delta T(x) = \Delta T_u + \Delta T_{th}\left(1 - \frac{4\pi \times x^2}{2\sqrt{3} \times N \times d^2}\right) \approx \Delta T_u + \Delta T_{th}\left(1 - \frac{3{,}63 \times x^2}{N \times d^2}\right) \text{ °C} \quad \text{(B.4)}$$

where

x is the distance from the centre of the bundle ($0 \le x \le$ bundle radius), in metres (m).

B.6 Alternative presentation of the model

An alternative approximation of the model enables the calculation of ΔT using a curve-fitting approach which provides a single value to allow comparison with simpler test set-ups where only the equivalent of measurements from thermocouples T_{2a} and T_A of Figure F.2 are used.

In such cases, the model equations of (B.2) and (B.3) can be combined and presented as follows:

$$\Delta T = C \times i_c{}^2 \times R \quad \text{(B.5)}$$

where

$$C \approx \frac{\rho_u \times n_c \times \sqrt{N}}{(5 \times d)} + \frac{\rho_{th} \times N \times n_c}{12{,}6} \quad \text{(B.6)}$$

This also allows ΔT to be presented as a function of d or N.

See Annex E for a recommended method to validate the model described in Annex B.

B.7 Adaptation model used to derive temperature rise vs. cables in a bundle

Based on the principles in Formulas (B.5) and (B.6), for a constant current, the predicted temperature rise for a bundle of cables will increase with the number of cables in the bundle.

The adaptation model describing this increase can be represented as shown in Formula (B.7).

$$\Delta T(I,N) = (C_1 N + C_2 \times \sqrt{N}) \times I^2 \quad \text{(B.7)}$$

where

ΔT is the temperature rise in °C,

I is the current in amperes,

N is the number of cables in the bundle,

C_1 is the coefficient that describes all variables associated with the geometry of the cable,

C_2 is the coefficient that describes all variables associated with the environment surrounding the cable bundle.

B.8 Calculations

For a fixed current and given cable bundle size, the temperature rise of the cable in the centre of the bundle can be measured. Another measurement can be made using the same cable type, same fixed current, and same environment surrounding the cable bundle, but with either a larger or smaller cable bundle size than the cable bundle already measured, The results of these two measurements provide the information needed to calculate the coefficients C_1 and C_2.

Stated mathematically, the first measurement result is shown symbolically in Formula (B.8).

$$\Delta T_1(I, N_1) = (C_1 N_1 + C_2 \times \sqrt{N_1}) \times I^2 \tag{B.8}$$

Stated mathematically, the second measurement result is shown symbolically in Formula (B.9).

$$\Delta T_2(I, N_2) = (C_1 N_2 + C_2 \times \sqrt{N_2}) \times I^2 \tag{B.9}$$

The coefficients C_1 and C_2 can be solved algebraically using Formulas (B.8) and (B.9).

An alternative method is to construct a matrix equation using Formulas (B.8) and (B.9) as shown in Formula (B.10).

$$\begin{bmatrix} \Delta T_1 \\ \Delta T_2 \end{bmatrix} = \begin{bmatrix} N_1 & \sqrt{N_1} \\ N_2 & \sqrt{N_2} \end{bmatrix} \times \begin{bmatrix} C_1 \\ C_2 \end{bmatrix} \times I^2 \tag{B.10}$$

Solving for the unknown variables results in Formula (B.11).

$$\begin{bmatrix} C_1 \\ C_2 \end{bmatrix} = \begin{bmatrix} N_1 & \sqrt{N_1} \\ N_2 & \sqrt{N_2} \end{bmatrix}^{-1} \times \begin{bmatrix} \Delta T_1 \\ \Delta T_2 \end{bmatrix} \times I^{-2} \tag{B.11}$$

B.9 Example

For a fixed current of 500 mA per conductor and cable bundle size of 37, the temperature rise of a Category 6 cable in the centre of the bundle in air is measured to be 7,26 °C.

Another measurement using the same cable type, same fixed current of 500 mA per conductor, and same air environment surrounding the cable bundle, but with a cable bundle size of 61, resulted in a temperature rise of the cable in the centre of the bundle of 11,10 °C.

Using these values and Formula (B.5) results in Formula (B.12).

$$\begin{bmatrix} C_1 \\ C_2 \end{bmatrix} = \begin{bmatrix} 37 & \sqrt{37} \\ 61 & \sqrt{61} \end{bmatrix}^{-1} \times \begin{bmatrix} 7{,}26 \\ 11{,}10 \end{bmatrix} \times (1{,}0)^{-2} \tag{B.12}$$

Solving Formula (B.12) gives the results for the coefficients C_1 and C_2 in Formula (B.13).

$$\begin{bmatrix} C_1 \\ C_2 \end{bmatrix} = \begin{bmatrix} 0{,}13 \\ 0{,}39 \end{bmatrix} \quad \text{(B.13)}$$

B.10 Coefficients for air and conduit

Table B.1 shows the bundling coefficients determined from measurements for the different cables and cords using at least two different bundle sizes (e.g. 37 and 61 cables per bundle). See Annex F for a recommended method to determine the constants for different types of cables and cords.

Table B.1 – Bundling coefficients for different types of cables and cords (all 4 pairs energized)

	Bundling coefficients			
	open air		conduit	
	C_1	C_2	C_1	C_2
0,4 mm cords	0,1445	1,7800	0,1980	2,9250
Cat 5 cables	0,1267	0,9933	0,1583	1,5300
Cat 6 cables	0,1057	0,7070	0,1206	1,1783
Cat 6_A cables	0,0857	0,6263	0,0926	0,9967
Cat 7 cables	0,0857	0,6263	0,0926	0,9967
Cat 7_A cables	0,0436	0,515	0,0555	0,841
NOTE The bundling coefficients for Cat 7_A cables were determined from the relative resistance values in IEC TR 61156-1-6.				

Annex C
(informative)

Transmission parameters related to remote powering

C.1 DC loop resistance

The DC loop resistance requirements of each pair of a channel are specified in ISO/IEC 11801-1 when measured in accordance with IEC 61935-1. For convenience, Table C.1 shows those requirements.

Table C.1 – Maximum DC loop resistance of channels

Category 5 Ω	Category 6 Ω	Category 6_A Ω	Category 7 Ω	Category 7_A Ω
25	25	25	25	25
NOTE DC loop resistance applies only to pairs that provide DC continuity end-to-end. For testing connectivity, refer to IEC 61935-1.				

While the values in Table C.1 represent the maximum DC loop resistance values specified, the actual DC loop resistance is dependent on the conductor size and length of the cabling. Selecting a larger conductor size, often associated with a higher-performance category of cabling, is one way to reduce DC loop resistance and improve both energy consumption and heating. Careful attention to cable routing to minimize cable lengths will substantially decrease DC loop resistance.

C.2 DC resistance unbalance (within pair)

The DC resistance unbalance requirements of each pair of a cable, connector, or channel are specified in ISO/IEC 11801-1. For convenience, Table C.2 shows those requirements as shown in Formula (C.1).

The resistance unbalance within a pair, $R_{\text{u,pair}}$, is defined by:

$$R_{\text{u,pair}} = \left\{ \frac{|R_{\text{c1}} - R_{\text{c2}}|}{R_{\text{c1}} + R_{\text{c2}}} \right\} \times 100\% \qquad \text{(C.1)}$$

where

R_{c1} is the DC resistance of one conductor in a pair,

R_{c2} is the DC resistance of the other conductor in the pair.

Table C.2 – DC resistance unbalance of cables, connecting hardware and channels

Category	Cable	Connecting hardware	Channel
Category 5	≤ 2,5 % [a]	≤ 50 mΩ [b]	≤ 3 % [e] or ≤ 200 mΩ [c,d] whichever is greater.
Category 6	≤ 2,5 % [a]		
Category 6_A, 7, 7_A	≤ 2,0 % [a,c]		

[a] When measured in accordance with IEC 61156-1 at, or corrected to, a temperature of 20 °C.

[b] Maximum difference between any two conductors of Category 5, 6, 6_A, 7, 7_A connecting hardware measured in accordance with IEC 60512-2-1:2002, Test 2a.

[c] Based on a DC resistance unbalance of each connection of 50 mΩ.

[d] As channel length decreases, the DC resistance unbalance becomes bounded by the DC resistance unbalance of the connecting hardware, ≤ 200 mΩ for four connectors. Therefore, as the contribution of the cable to total channel DC resistance decreases, it is possible for the DC resistance unbalance expressed as a percentage to exceed 3 %.

[e] When measured in accordance with IEC 61935-1.

C.3 DC resistance unbalance (pair to pair)

The pair-to-pair DC resistance unbalance $R_{\text{u,between pairs}}$ is defined by Formula (C.2).

$$R_{\text{u,between pairs}} = \left\{ \frac{\left| R_{\text{p1}} - R_{\text{p2}} \right|}{R_{\text{p1}} + R_{\text{p2}}} \right\} \times 100\% \qquad \text{(C.2)}$$

where

R_{p1} is the DC parallel resistance of the conductors of a pair,

R_{p2} is the DC parallel resistance of the conductors of another pair.

and

$$R_{\text{p}x} = R_{\text{c1}} \times R_{\text{c2}} \,/\, (R_{\text{c1}} + R_{\text{c2}})$$

where

R_{c1} is the DC resistance of one conductor in a pair,

R_{c2} is the DC resistance of the other conductor in the pair.

The DC resistance unbalance (pair to pair) requirements of a cable, permanent link, or channel are shown in Table C.3. The requirements for DC resistance unbalance are based on statistical analysis of a survey of installed cabling.

Table C.3 – DC resistance unbalance (pair to pair)

Category/Class	Cable	Permanent link [a,b]	Channel [a,b]
Category 5/Class D	5 %	7 % or 0,1 Ω, whichever is greater	7 % or 0,1 Ω, whichever is greater
Category 6/Class E			
Category 6_A /Class E_A			
Category 7/ Class F			
Category 7_A /Class F_A			

[a] As channel and permanent link length decreases, the DC resistance unbalance becomes bounded by the DC resistance unbalance of the connecting hardware, ≤ 100 mΩ for four connectors on two pairs in parallel. Therefore, as the contribution of the cable to total channel DC resistance decreases, it is possible for the DC resistance unbalance expressed as a percentage to exceed 7 %. Field measurements may have accuracy limitations below 0,2 Ω.

[b] When measurements of DC loop resistance are used to calculate pair-to-pair DC resistance unbalance, the accuracy of measurements of DC loop resistance for both pairs should be taken into consideration (see IEC 61935-1).

Annex D
(informative)

Illustrations of heating of various bundle sizes and configurations

D.1 Limiting cable bundle size

Separating large bundles into smaller bundles reduces the maximum temperature rise when it results in a larger separation or overall surface area (e.g. 3 × 37-cable bundles had lower temperature rise than a 91-cable bundle).

The measured temperature rise in the centre of a 91-cable bundle shown in Figure D.1 was higher than the worst case measured temperature rise in the centre of three smaller bundles of 37 cables as shown in Figure D.2.

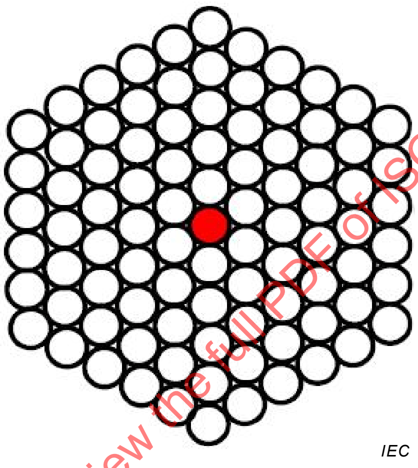

Figure D.1 – 91-cable bundle

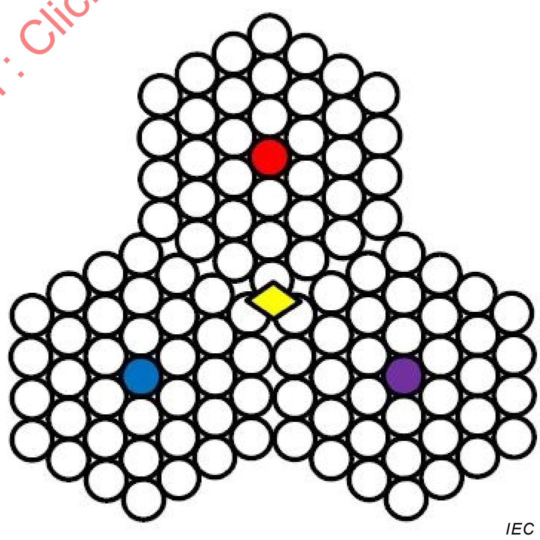

Figure D.2 – Three bundles of 37 cables

D.2 Separating into smaller bundles

Separation of bundles into three bundles as illustrated in Figure D.3 reduces the maximum temperature rise even further.

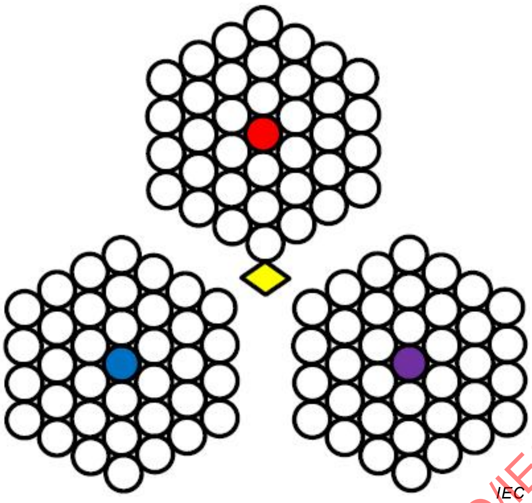

Figure D.3 – Three bundles of 37 cables with separation

Annex E
(informative)

Test protocol

E.1 Background

The testing protocol detailed in Annex E is intended for the determination and collation of information in laboratory conditions. It may be applied to assess the performance of specific products in the configuration specified within the protocol, but is not intended to be applied as acceptance testing for such products or for installed cabling.

The testing protocol is required to be able to measure the temperatures of conductors, cables and cable bundles for the models in Annex B based upon the variables of i_c, n_c, N and R.

The test protocol provides test configurations, methods and data submission formats that are necessary to produce effective comparative data which support the planning, installation and operational recommendations of this document.

E.2 Test set-up

All tests shall be undertaken on bundles containing thirty-seven (37) 4-pair cables each having a nominally circular cross-section. This quantity is used in order to produce a cable bundle with three complete layers surrounding a centre cable as shown in Figure E.1.

NOTE 1 Circular bundles can be constructed with lower numbers of cables (e.g. 7 or 19, where smaller containment systems are under investigation), but these are considered inappropriate for the needs of the recommendations of this document.

NOTE 2 Thermocouples T_{2b} and T_{2c} are optional and are only necessary for data intended to validate the model of Annex B.

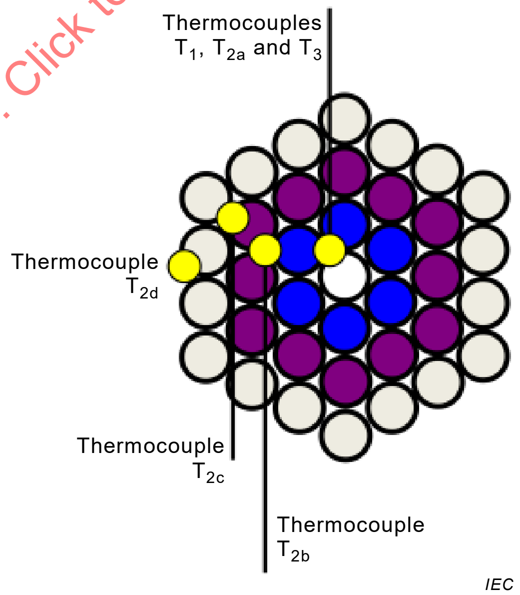

Figure E.1 – 37-cable bundle and temperature location

The minimum length of the “perfect bundle”, i.e. that length over which the bundle is configured with three complete layers surrounding a centre cable in a circular construction, is 2,4 m. This is shown in Figure E.2.