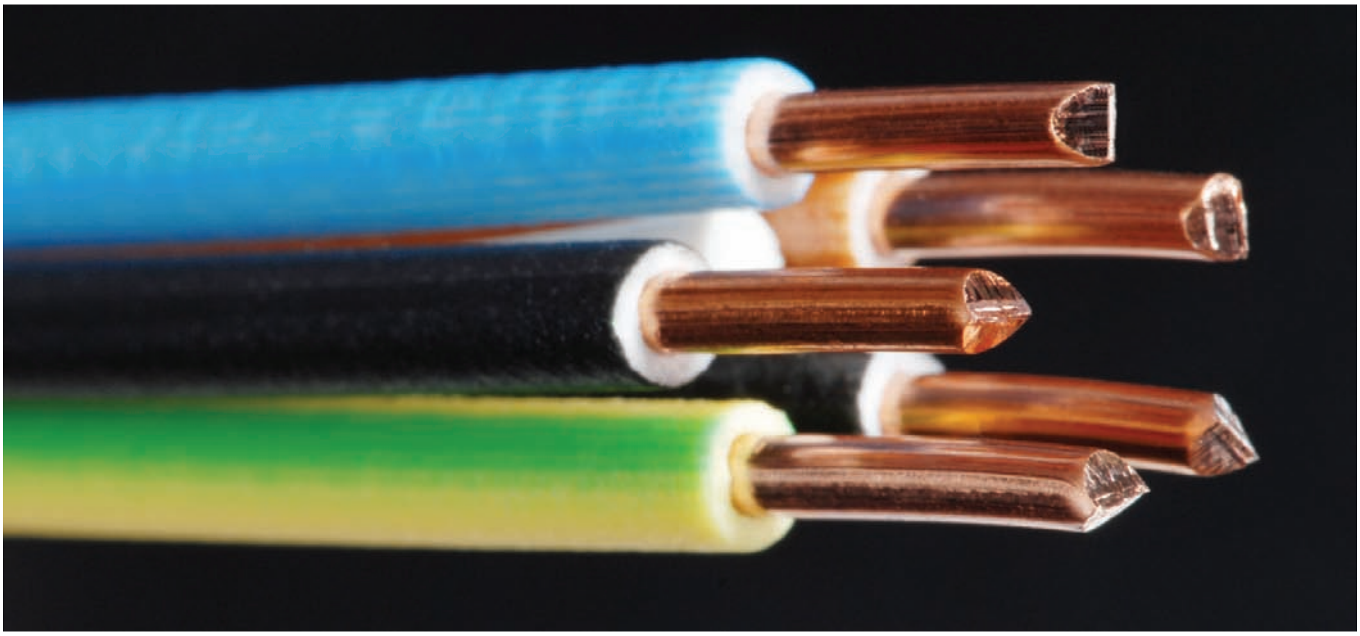


Appendix 4 of BS 7671

by Mark Coles

Appendix 4, *Current-carrying capacity and voltage drop for cables and flexible cords*, has seen significant changes with the publishing of BS 7671:2008. This article looks at some of the changes and shows examples of cable calculations.

SELECTING THE correct cable for the application is imperative to ensure a satisfactory life of conductors and insulation subjected to the thermal effects of carrying current for prolonged periods of time in normal service.

Choosing the minimum size cross-sectional area of conductors is essential to meet the requirements for:

- Protection against electric shock (Chapter 41)
- Protection against thermal effects (Chapter 42)
- Overcurrent protection (Chapter 43),
- Voltage drop (Section 525), and
- Limiting temperatures for terminals of equipment to which the conductors are connected (Section 526).

Current-carrying capacity and voltage drop for cables

The 17th Edition brought about some significant changes when calculating the current-carrying capacity and voltage drop for cables. For both the 16th and 17th Editions, most of the current ratings have been taken from IEC 60364-5-52 and the CENELEC HD 384.5.52 +A1 1998. These IEC and CENELEC documents do not, however, provide current ratings for armoured single-core cables, therefore, the ratings for these cables are based on data provided by ERA Technology Ltd and the British Cables Association.
The tables have been updated to reflect present cable standards and introduce current ratings for buried cables. Generally, the current ratings for commonly used cables have not changed between the 16th and 17th Editions.

Installation methods

The 16th Edition recognised 20 methods of installation, the 17th Edition, however, recognises 57 methods in Table 4A2. It is impossible, of course, to cover every possible method or installation permutation but, with the 17th Edition recognising a further 37 methods of installation, more possibilities are now covered. Note that all installation numbers in table 4A2 are different from those in the 16th Edition.

Reference method

It is impractical to calculate and publish current ratings for every installation method, since many would result in the same current rating. Therefore a suitable (limited) number of current ratings have been calculated which cover all installation methods, known as Reference Methods. There are 7 reference methods, A to G, shown in table 1 overleaf.

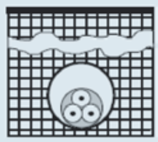
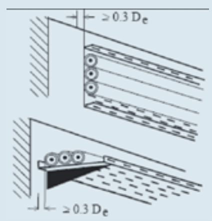
Reference method	Example of installation method		Relevant table from BS 7671:2008	Image
A	Non-sheathed cables in conduit in a thermally insulated wall	The wall consists of an outer weatherproof skin, thermal insulation and an inner skin of wood or wood-like material having a thermal conductance of at least 10 $W/m^2.K$. The conduit is fixed such that it is close to, but not necessarily touching, the inner skin. Heat from the cables is assumed to escape through the inner skin only. The conduit can be metal or plastic.	Installation Method 1 of Table 4A2	
	Multicore cables in conduit in a thermally insulated wall		Installation Method 2 of Table 4A2	
B	Non-sheathed cables in conduit mounted on a wooden or masonry wall	The conduit is mounted on a wooden wall such that the gap between the conduit and the surface is less than 0.3 times the conduit diameter. The conduit can be metal or plastic. Where the conduit is fixed to a masonry wall the current-carrying capacity of the non-sheathed or sheathed cable may be higher.	Installation Method 4 of Table 4A2	
	Multicore cables in conduit mounted on a wooden or masonry wall		Installation Method 5 of Table 4A2	
C (clipped direct)	Single-core or multicore cable on a wooden or masonry wall	Non-sheathed cables in conduit mounted on a wooden or masonry wall	Installation Method 20 of Table 4A2	
D	Multicore unarmoured cable in conduit or in cable ducting in the ground	Non-sheathed cables in conduit mounted on a wooden or masonry wallThe cable is drawn into a 100 mm diameter plastic, earthenware or metallic duct laid in direct contact with soil having a thermal resistivity of 2.5 K.m/W and at a depth of 0.8 m. The values given for this method are those stated in this appendix and are based on conservative installation parameters. If the specific installation parameters are known (thermal resistance of the ground, ground ambient temperature, cable depth), reference can be made to the cable manufacturer or the ERA 69-30 series of publications, which may result in a smaller cable size being selected. NOTE: The current-carrying capacity for cables laid in direct contact with soil having a thermal resistivity of 2.5 K.m/W and at a depth of 0.7 m is approximately 10 % higher than the values tabulated for Reference Method D	Installation Method 70 of Table 4A2	
E, F and G	Single-core or multicore cable in free air	The cable is supported such that the total heat dissipation is not impeded. Heating due to solar radiation and other sources is to be taken into account. Care is to be taken that natural air convection is not impeded. In practice, a clearance between a cable and any adjacent surface of at least 0.3 times the cable external diameter for multicore cables or 1.0 times the cable diameter for single-core cables is sufficient to permit the use of current-carrying capacities appropriate to free air conditions.	Installation Method 70 of Table 4A2	

Table 1: Reference methods

Other methods of installation

Other methods of installation are recognised but are, essentially, variations of other methods and are therefore allocated appropriate reference methods, shown in table 2 overleaf.

It is worth noting that the 17th Edition now references cables buried in the ground (installation methods 70 to 73). The current-carrying capacities tabulated for cables in the ground are based upon a soil thermal resistivity of 2.5 K.m/W and are intended to be applied to cables laid in and around buildings, i.e. disturbed soil. For other installations, where investigations establish more accurate values of soil thermal resistivity appropriate for the load to be carried, the values of current-carrying capacity may be derived by the methods of calculation given in BS 7769 (BS IEC 60287) or obtained from the cable manufacturer.

In locations where the effective soil thermal resistivity is higher than 2.5 K.m/W, an appropriate reduction in current-carrying capacity should be made or the soil immediately around the cables should be replaced by a more suitable material, i.e. such cases can usually be recognised by very dry ground conditions. Rating factors for soil thermal resistivities other than 2.5 K.m/W are given in Table 4B3.

Flat, twin and earth cables installed in thermal insulation are also recognised by installation methods 100 to 103.

Example of installation method	Reference method
Cable on a floor	Reference Method C applies for current rating purposes.
Cable under a ceiling	This installation may appear similar to Reference Method C but because of the reduction in natural air convection, Reference Method B is to be used for the current rating.
Cable tray systems	A perforated cable tray has a regular pattern of holes that occupy at least 30% of the area of the base of the tray. The current-carrying capacity for cables attached to perforated cable trays should be taken as Reference Methods E or F. The current-carrying capacity for cables attached to unperforated cable trays (no holes or holes that occupy less than 30% of the area of the base of the tray) is to be taken as Reference Method C.
Cable ladder system	This is a construction which offers a minimum of impedance to the air flow around the cables, i.e. supporting metalwork under the cables occupies less than 10% of the plan area. The current-carrying capacity for cables on ladder systems should be taken as Reference Methods E or F.
Cable cleats, cable ties and cable hangers	Cable supports hold the cable at intervals along its length and permit substantially complete free air flow around the cable. The current-carrying capacity for cable cleats, cable ties and cable hangers should be taken as Reference Methods E or F.
Cable installed in a ceiling	This is similar to Reference Method A. It may be necessary to apply the rating factors due to higher ambient temperatures that may arise in junction boxes and similar mounted in the ceiling. NOTE: Where a junction box in the ceiling is used for the supply to a luminaire, the heat dissipation from the luminaire may provide higher ambient temperatures than permitted in Tables 4D1A to 4J4A (see also Regulation 522.2.1). The temperature may be between 40 °C and 50 °C, and a rating factor according to Table 4B1 must be applied.

Table 2: **Other recognised methods of installation**

Sizing of cables

Relationship of current-carrying capacity to other circuit parameters
The relevant symbols used in the Regulations are shown in Table 3:

Iz	It	Ib
The current-carrying capacity of a cable for continuous service, under the particular installation conditions concerned.	The value of current tabulated in this appendix for the type of cable and installation method concerned, for a single circuit in the ambient temperature stated in the current-carrying capacity tables.	The design current of the circuit, i.e. the current intended to be carried by the circuit in normal service. In the rated current or current setting of the protective device.
In	**I2**	**C**
The rated current or current setting of the protective device.	The operating current (i.e. the fusing current or tripping current for the conventional operating time) of the device protecting the circuit against overload.	A rating factor to be applied where the installation conditions differ from those for which values of current-carrying capacity are tabulated in this appendix.
The various rating factors are identified as follows:		
Ca	**Cg**	**Ci**
For ambient temperature.	For grouping.	For thermal insulation.
Ct	**Cc**	
For operating temperature of conductor.	For the type of protective device or installation condition.	

Table 3: **Symbols used in the Regulations**

The rated current or current setting of the protective device (*In*) must not be less than the design current (*Ib*) of the circuit, and the rated current or current setting of the protective device (*In*) must not exceed the lowest of the current-carrying capacities (*Iz*) of any of the conductors of the circuit, see fig. 1.

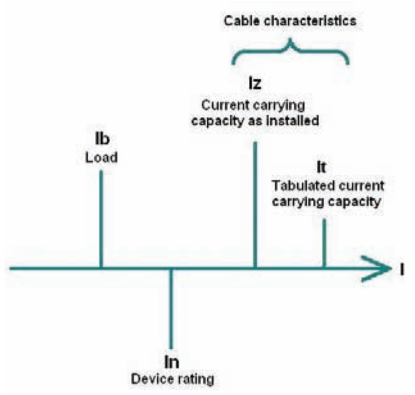


Fig. 1: Coordination of load, device and cable characteristics

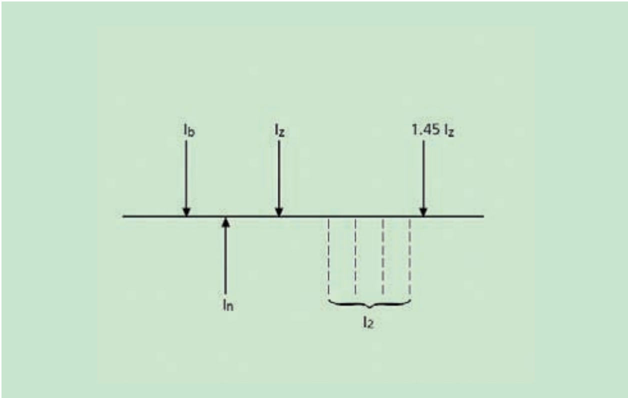


Fig. 2: Coordination for overload protection

Where the overcurrent device is intended to afford protection against overload, I_2 must not exceed 1.45 *Iz* and In must not exceed *Iz*, see fig. 2.

Where the overcurrent device is intended to afford fault current protection only, *In* can be greater than *Iz* and I_2 can be greater than 1.45 *Iz*. The protective device must be selected for compliance with Regulation 434.5.2.

Determination of the size of cable to be used

When overcurrent protection is to be provided, the current-carrying capacity of the cable, *Iz*, is determined by applying correction factors to the tabulated cable ratings, *It*, from Appendix 4 of BS 7671.

Iz = It Ca Cg Ci Cc

where:

Ca is rating factor for ambient temperature, see Table 4B1 of BS 7671
Cg is rating factor for grouping see, Table 4C1 of BS 7671
Ci is rating factor for conductors surrounded by thermal insulation
Cc is a rating factor applied when overload protection is being provided by an overcurrent device with a fusing factor greater than 1.45, e.g. *Cc* = 0.725 for semi-enclosed fuses to BS 3036, and when the cable is laid in the ground.

By referring to fig. 1, the current-carrying capacity of the cable, *Iz*, must equal or exceed the circuit overcurrent device rated current, *In*.

Iz ≥ In

and, hence, by combining the two equations above, we get:

$$I_t \geq \frac{I_n}{C_a C_g C_i C_c}$$

This equation can be read as, when overcurrent protection is to be provided, the tabulated cable ratings from Appendix 4 of BS 7671 must equal or exceed the circuit overcurrent device rating corrected for ambient temperature, grouping, thermal insulation and the use of a rewirable fuse if applicable.

Example 1

A circuit supplying a shower with a loading of 6 kW would have a design current *Ib* given by:

$$I_b = \frac{6 \times 1000 \text{ W}}{230 \text{ V}} = 26 \text{ A}$$

The nominal current rating in amps, *In*, of the protective device (fuse or circuit-breaker) for a circuit is selected so that *In* is greater than or equal to the design current, *Ib*, of the circuit.

In ≥ Ib

So, in the example of the 6 kW shower *In* must be ≥ 26;

select say a 32 A circuit-breaker, that is

In = 32 A

A cable must now be selected so that its rating, *Iz*, in the particular installation conditions exceeds the design current of the load, *Ib*.

Iz ≥ Ib

In the example of the 6 kW shower load, *Ib* = 26, so *Iz* ≥ 26.

Where overload protection of the cable is to be provided, as is usual, the cable is also selected so that its rating in its installed conditions *Iz* exceeds the current rating of the circuit protective device.

Iz ≥ In

In the example of the 6 kW shower circuit with overload protection, *Iz* ≥ 32. It may be argued that no overload need be provided for a shower as the load is fixed.

Therefore, Iz ≥ In ≥ Ib

In the example of the 6 kW shower with overload protection, this relationship will be satisfied if *Ib* = 26 A, *In* = 32 A and the circuit conductors are sized such that *Iz* ≥ 32 A.

To calculate the tabulated cable ratings, It, the following formula (from Appendix 4 of BS 7671) is used.

Iz = It Ca Cg Ci Cc

Overload protection is provided in practically all circuit designs in order to protect the cable should the load be increased, e.g. by adding further lights to a lighting circuit or changing a shower for one of a higher rating without proper checks being made.

However, for a fixed load e.g. a shower circuit, this is not an actual requirement of BS 7671.
Note that the term overcurrent includes both overload current and fault current.

Where protection is being provided against overload, protection will also be provided against fault currents, however, the reverse is not true

Knowing *Iz*, it is necessary to select a tabulated cable rating such that

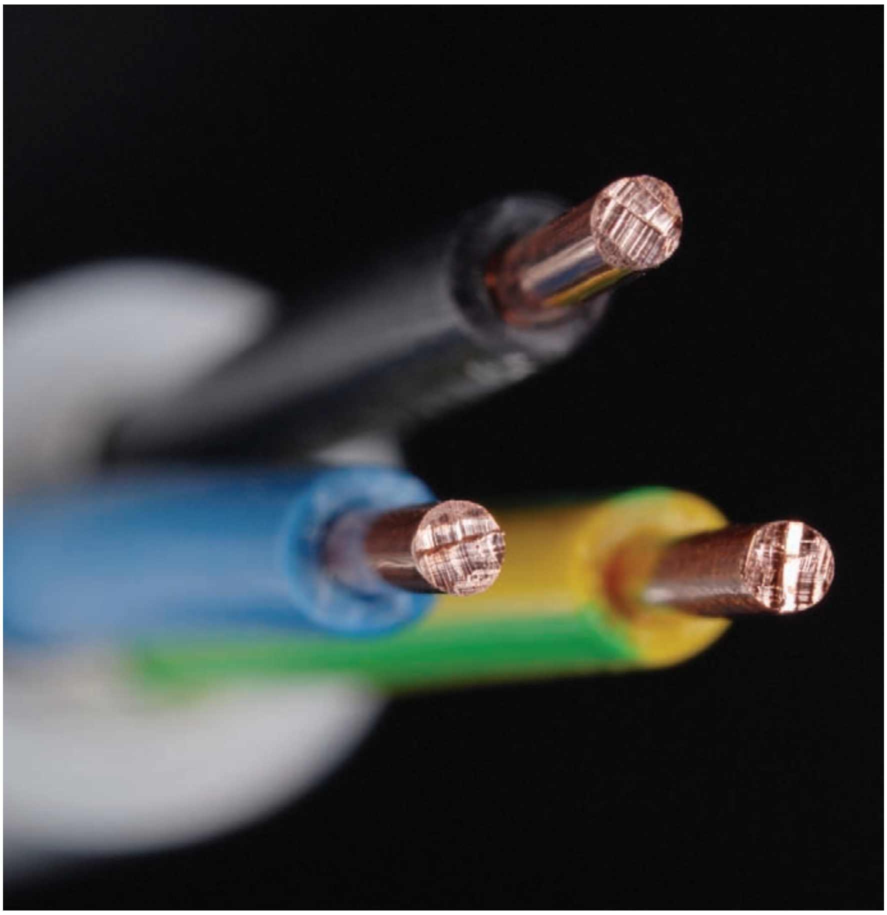
$$I_t \geq \frac{I_z}{C_a C_g C_i C_c}$$

Example 2

For the shower circuit above:
the ambient temperature is assumed (as is usual) to be 30 °C, so *Ca* = 1
the cable is not grouped so *Cg* = 1
the cable is not installed in thermal insulation so *Ci* = 1, and
it is not a semi-enclosed (rewirable fuse) so *Cc* = 1.

Hence

$$I_t \geq \frac{32}{1 \times 1 \times 1 \times 1}$$



For a thermoplastic (PVC) insulated and sheathed flat cable with protective conductor from Table C.1 or Table 4D5A of BS 7671 or Table 6F of the On-Site Guide, installed in an insulated wall, 6 mm^2 cable is adequate as it has a tabulated rating of 32 A for installation method A.

Further information

Further information and reading can be found in the following publications:

- BS 7671:2008 *Requirements for Electrical Installations, IEE Wiring Regulations, Seventeenth Edition Guidance Note 3 - Inspection and Testing*
- Electrical Installation Design Guide - Calculations for Electricians and Designers (2008), IET publication ISBN 978-0-86341-550-0
- IET Guidance Note 6 - Protection against overcurrent
- BS 7769 (BS IEC 60287) *Electric cables. Calculation of the current rating. Thermal resistance. A method for calculating reduction factors for groups of cables in free air, protected from solar radiation*
- IEC 60502-1 *Power cables with extruded insulation and their accessories for rated voltages from 1 kV (Um = 1,2 kV) up to 30 kV (Um = 36 kV) – Part 1: Cables for rated voltages of 1 kV (Um = 1,2 kV) and 3 kV (Um = 3,6 kV)*
- BS EN 60228 *Conductors of insulated cables*
- *IEC 364-5-523: 1983 Electrical installations of buildings - Part 5: Selection and erection of electrical equipment. Chapter 52: Wiring systems. Section 523 - Current-carrying capacities* ■