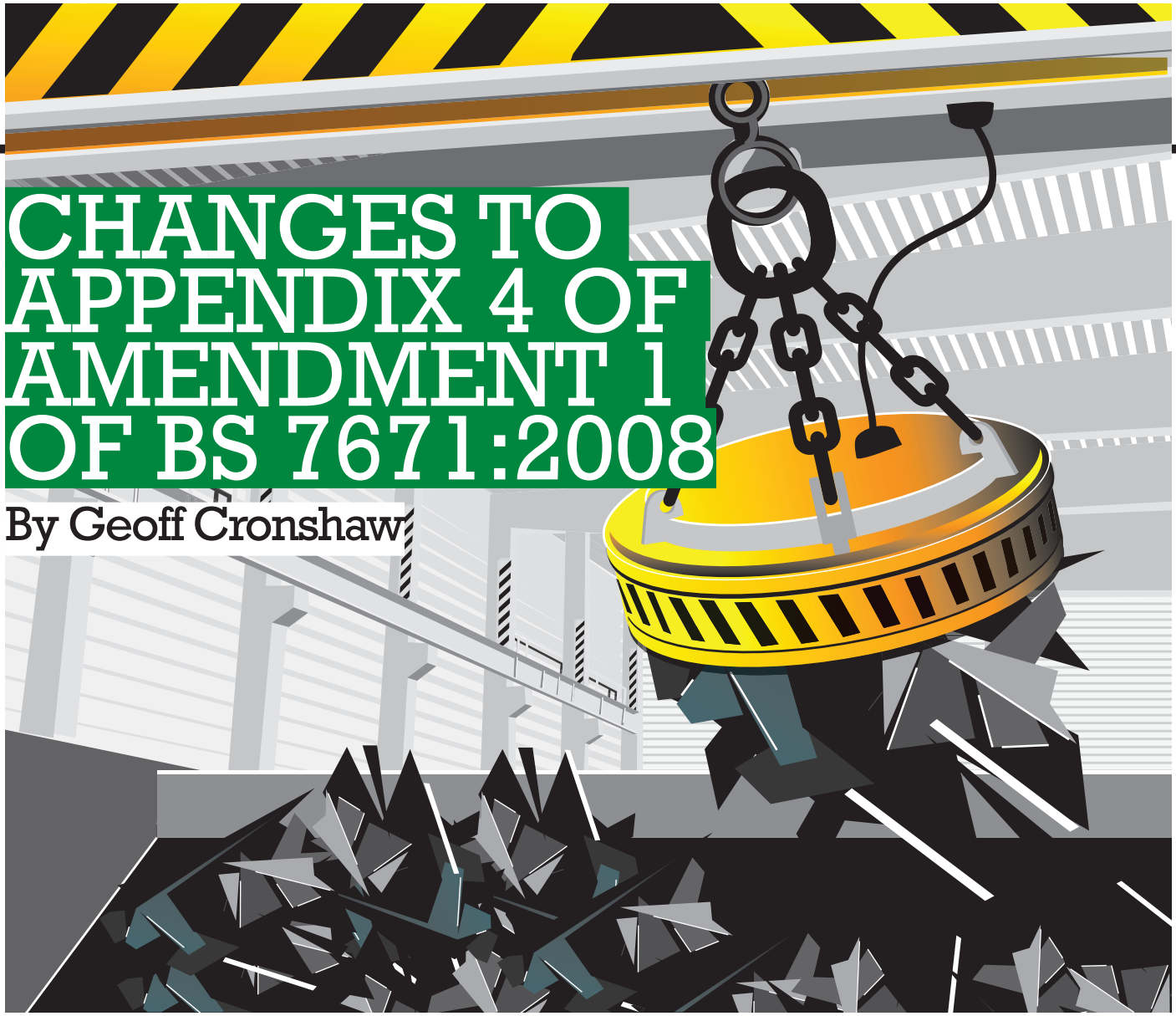


CHANGES TO APPENDIX 4 OF AMENDMENT 1 OF BS 7671:2008

By Geoff Cronshaw

Amendment 1 of the 17th edition of the Wiring Regulations brought changes to Appendix 4: selection of conductor cross sectional area (article excludes voltage drop and fault current calculations)

THE CURRENT-CARRYING capacity of a cable corresponds to the maximum current that can be carried in specified conditions without the conductors exceeding the permissible limit of steady-state temperature for the type of insulation concerned. The values of current tabulated represent the effective current-carrying capacity only where no rating factor is applicable.

A rating factor has to be applied where the installation conditions differ from those for which values of current-carrying capacity are tabulated in Tables 4D1A to Tables 4J4A of Appendix 4. The first significant change introduced in the 17th edition, compared with the 16th edition, is the large number of rating factors related to cables buried in the ground.

Selection of conductor cross-sectional area with overload protection

The required tabulated current rating (I_t) of a cable where overload protection is to be provided is given by:

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

Where:

I_t is the tabulated current-carrying capacity of a cable found in Appendix 4 of BS 7671;

I_n is the rated current or current setting of the overcurrent device;

C_g is rating factor for grouping;

C_a is rating factor for ambient temperature;

C_i is rating factor for conductors surrounded by thermal insulation;

C_f is rating factor for semi-enclosed fuses (BS 3036);

C_s is rating factor for thermal resistivity of soil;

C_c is rating factor of 0.9 for cables buried in the ground (otherwise 1);

C_d is rating factor for depth of buried cable.

Note: when overload protection is required the current carrying capacity of the cable has to be related to the current rating of the overload protective device (I_n).The correction factors are applied as divisors to I_n. For example, the circuit breaker standard (BS EN 60898) refers to 1.45 multiplied by I_n as the conventional tripping current which must open the circuit breaker contacts within the conventional time. This is defined as one or two hours depending on the current rating of the circuit breaker. The factor of 1.45 ensures that deterioration of cables does not result from small overloads.

Selection of conductor cross-sectional area for circuits not requiring overload protection

Regulation 433.3 describes the circumstances where overload protection may be omitted. If a load cannot vary, especially increase, overload protection may not be necessary; however, fault protection (short-circuit and earth fault) will still (with a few exceptions, see Regulation 434.3) be required.

Overload protection may be omitted where:

I_t is not needed (Regulation 433.3.1);

Unexpected disconnection could cause danger or damage (Regulation 433.3.3).

Note: This omission of overload protection must not be applied to installations situated in locations presenting a fire risk, or risk of explosion, or where the requirements for special installations and locations (Part 7 of BS 7671) specify different conditions.

Regulation 433.3.3 allows the omission of devices for protection against overload for circuits supplying current-using equipment where unexpected disconnection of the circuit could cause danger or damage. For example, the supply circuit of a lifting magnet. Electromagnets are used, for example, in scrapyards to lift and carry loads. If such a magnet is de-energised while in operation this could cause damage or injury.

Note: In such situations consideration should be given to the provision of an overload alarm.

Omission of the need for overload protection simplifies the equation for the required tabulated current rating, as C_f and C_c are unity.

The equation for required I_t then becomes:

$$I_t \geq \frac{I_b}{C_g C_a C_i C_s C_d}$$

Where:

I_t is the tabulated current-carrying capacity of a cable found in Appendix 4 of BS 7671;

I_b is the design (load) current of the circuit;

C_g is rating factor for grouping;

C_a is rating factor for ambient temperature; ≥

C_i is rating factor for conductors surrounded by thermal insulation;

C_s is rating factor for thermal resistivity of soil;

C_d is rating factor for depth of buried cable.

Note: where the cable will not be subject to overload and there is no need for overload protection, the correction factors are simply applied as divisors to the design current (load current) of the circuit (I_b) to ensure the correct current carrying capacity of the cable is determined for the installed conditions.

Cable grouping (C_g)

Appendix 4 contains group rating factors contained in Tables 4C1 to 4C6. The 17th edition, published in 2008, introduced new grouping factors for buried cables. Two important points to note regarding grouping factors are:

Note 1 to Table 4C1 of BS 7671,which advises that the rating factors are applicable to uniform groups of cables, equally loaded. Regulation 523.5 states: the group rating factors, see Tables 4C1 to 4C6 of Appendix 4, are applicable to groups of non-sheathed or sheathed cables having the same maximum operating temperature. For groups containing non-sheathed or sheathed cables having different maximum operating temperatures, the current-carrying capacity of all the non-sheathed or sheathed cables in the group shall be based on the lowest maximum operating temperature of any cable in the group together with the appropriate group rating factor.

Clearly, care has to be taken in its application to groups of cables with different sizes. For example, thermosetting and thermoplastic cables should not be grouped unless the thermosetting cables' cross-sectional areas are selected as for thermoplastic cables.

Section 2.3.3 of Appendix 4 of BS 7671 provides guidance on grouping of different sized cables. The group rating factor for groups in conduit, trunking or ducting systems is given by:

$$F = \frac{1}{\sqrt{n}}$$

Where:

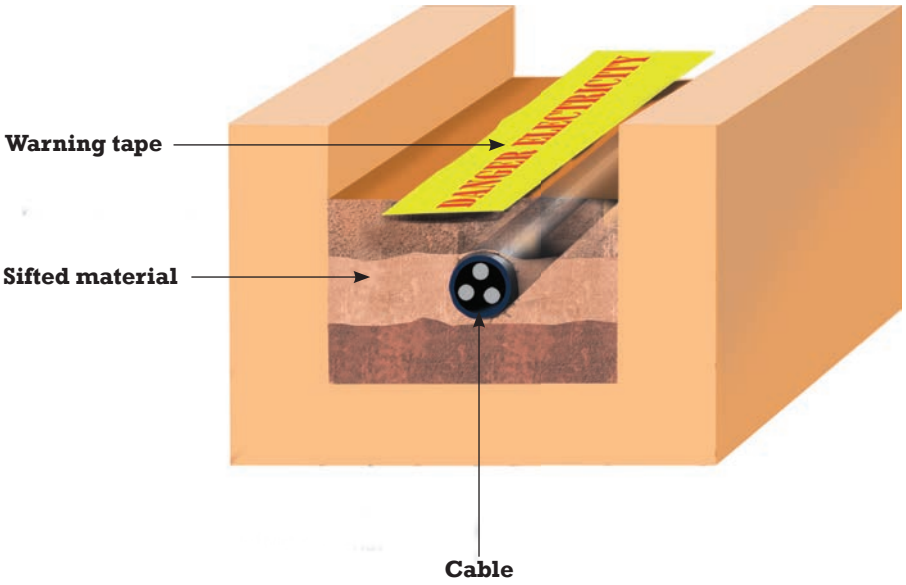
F is the group rating factor (C_g);

n is the number of circuits in the group.

The second important note, Note 9 to Table 4C1, is especially significant. It notes that cables with a loading of less than 30 per cent of the grouped rating may be discounted (ignored) and the rating of the remaining cables calculated as if the lightly loaded cables were not included in the group.

Ambient temperature (C_a)

Appendix 4 includes tabulated current-carrying capacities for some of the most commonly used cables in the electrical installation industry. These tabulated current carrying capacities are based upon a 30°C ambient temperature for



cables (other than buried in the ground) and 20°C ambient ground temperature for cables buried in the ground. Where the installation conditions differ, a correction factor has to be applied – detailed in Tables 4B1 and 4B2 of appendix 4. Note that where the ambient temperature varies over the route of the cable, the highest ambient temperature likely to be accounted has to be used as the basis for determining the current-carrying capacity.

Thermal insulation (C_i)

Regulation 523.9 states: For a single cable likely to be totally surrounded by thermally insulating material over a length of 0.5m or more, the current-carrying capacity shall be taken, in the absence of more precise information, as 0.5 times the current-carrying capacity for that cable clipped direct to a surface and open (Reference Method C).

Where a cable is to be surrounded by thermal insulation for less than 0.5m the current-carrying capacity of the cable shall be reduced depending on the size of cable, length in insulation and thermal properties of the insulation.

The derating factors in Table 52.2 (reproduced below) are appropriate to conductor sizes up to 10mm^2 in thermal insulation having a thermal conductivity (λ) greater than 0.04Wm^{-1}K^{-1}.

One important point to note is that a rating factor only has to be applied where the installation conditions differ from those for which values of current-carrying capacity are tabulated in the tables of Appendix 4. Therefore this correction factor (C_i) needs to be applied with great care as a number of tabulated current ratings in Appendix 4 already allow for contact with some thermal insulation. For example, Table 4D5 gives values of current-carrying capacity for cables in contact with thermal insulation, and, where these are used, no further correction needs to be made.

TABLE 52.2 – Cable surrounded by thermal insulation

Length in insulation (mm)	Derating factor
50	0.88
100	0.78
200	0.63
400	0.51

Rewireable fuse (C_f)

Those fuses referred to as 'rewirable fuses' are correctly termed semi-enclosed fuses (complying with BS 3036) as they are partially enclosed within the fuse-carrier. Regulation 533.1.1.3 of Amendment 1 of BS 7671:2008 states that a fuse shall preferably be of the cartridge type (but this does not preclude the use and installation of semi-enclosed fuses). The regulation states that where a semi-enclosed fuse is selected, it shall be fitted with an element in accordance with the manufacturer's instructions, if any. In the absence of such instructions, it shall be fitted with a single element of tinned copper wire of the appropriate diameter specified in Table 53.1.

The size needed for a conductor protected against overload by a BS 3036 semi-enclosed fuse can be obtained by the use of a rating factor, 1.45/2 = 0.725, which results in the same degree of protection as that afforded by other overload protective devices.

Cables buried in the ground - ambient ground temperature related to overload protection (C_c)

It is important to note that the tabulated current-carrying capacities for cables direct in ground or in ducts in the ground, given in Appendix 4, are based on an ambient ground temperature of 20°C. The factor of 1.45 that is applied in Regulation 433.1.1 when considering overload protection assumes that the tabulated current-carrying capacities are based on an ambient air temperature of 30°C. To achieve the same degree of overload protection for an ambient temperature of 20°C, a rating factor of 0.9 is applied as a multiplier to the tabulated current carrying capacity.

Cables buried in the ground - depth of cable (C_d).

Where cables are at depths other than 0.7m, direct buried or buried in ducts, Table 4B4 gives rating factors (C_d)

Cables buried in the ground – soil thermal resistivity (C_s)

The current-carrying capacities tabulated for cables in the ground are based upon a soil thermal resistivity of 2.5K.m/W and are intended to be applied to cables laid in and around buildings, i.e. disturbed soil.

In locations where the effective soil thermal resistivity is higher than 2.5K.m/W, an appropriate reduction in current-carrying capacity should be made. Rating factors for soil thermal resistivities other than 2.5K.m/W are given in Table 4B3.

OVERCURRENT PROTECTIVE DEVICES – CIRCUIT BREAKERS

There are many types of circuit breaker available, the most common being the 'thermal magnetic circuit breaker'. 'Miniature circuit breakers' (MCBs) should comply with BS EN 60898, entitled: 'Circuit-breakers for Overcurrent Protection for Household and Similar Installations'. The scope identifies they are designed for use by an uninstructed person. The maximum rated current permitted is 125A.

Thermal trip

A thermal bi-metallic trip is used to protect against overload currents. The bimetallic or thermal sensing element deflects mechanically as current passes through it. The higher the overcurrent, >

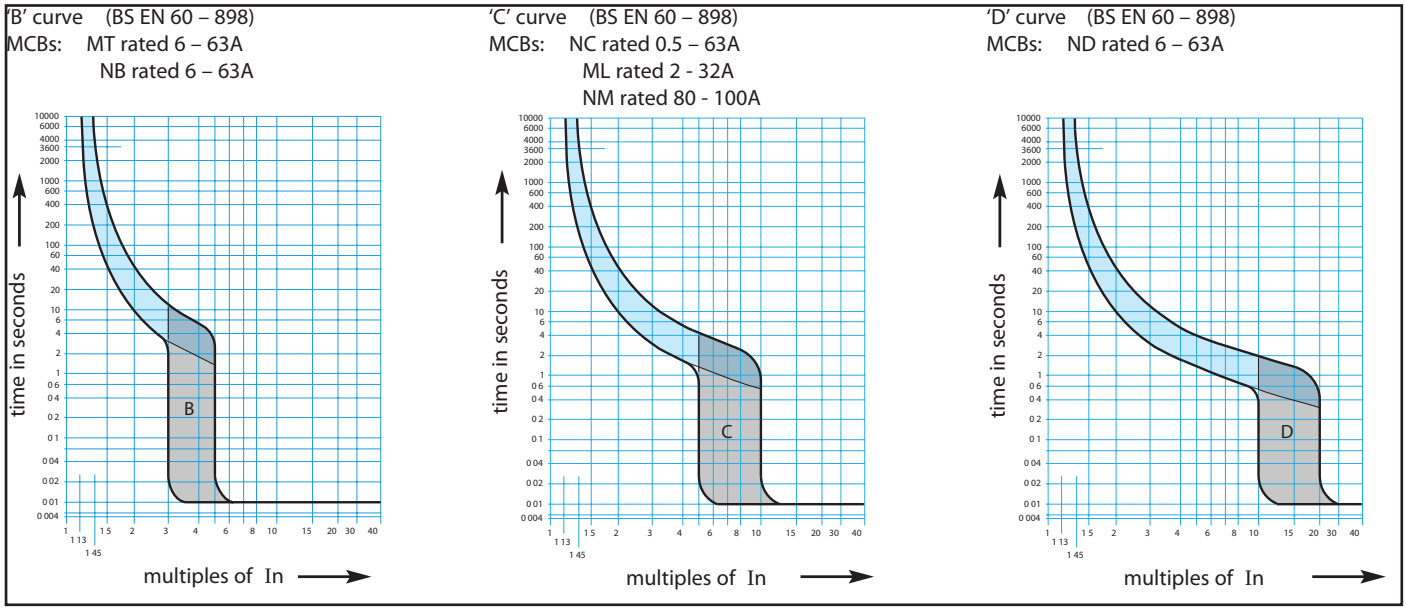


Fig 2: Circuit breaker curves

the greater the deflection. At a predetermined point the element will actuate a tripping mechanism, open the contacts and disconnect the circuit. This action is represented by the inverse time characteristic (curved section) of the circuit breaker - see Fig 1. The Standard BS EN 60898 refers to $1.45I_n$ as the conventional tripping current which must open the circuit breaker

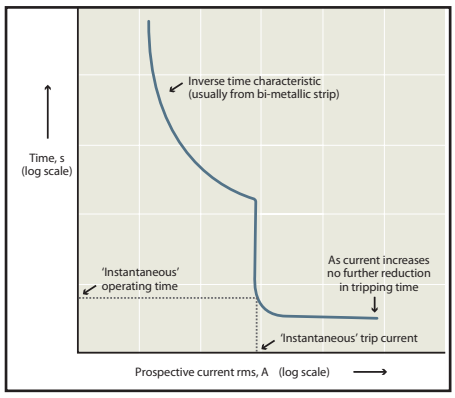


Fig 1: Circuit breaker

contacts within the conventional time. This is defined as one or two hours.

$1.45I_n$ relates directly to circuit design, in section 433 protection against overload current, regulation 433.1.1 states that: "the operating characteristics of a device protecting a conductor against overload shall satisfy the following conditions:

(i) the rated current or current setting of the protective device (I_n) is not less than the design current (I_b) of the circuit, and

(ii) the rated current or current setting of the protective device (I_n) does not exceed the lowest of the current-carrying capacities (I_z) of any of the conductors of the circuit, and

(iii) the current (I_2) causing effective operation of the protective device does not exceed 1.45 times the lowest current carrying capacities (I_z) of any of the conductors of the circuit."

The factor 1.45 ensures that deterioration of cables does not result from small overloads. This is based upon practical studies and experience that has shown when a current of 1.45 times the current carrying capacity of the cable is interrupted within the conventional times, there is no significant deterioration in the working life of the cable.

Magnetic characteristic

The magnetic characteristics on BS EN 60898 circuit breakers are fixed. Devices with a common nominal current rating are available in three different types. A letter preceding the nominal current rating i.e. B20 for a 20A type B circuit breaker denotes the type of device. The letters B, C, or D relate to the magnetic trip setting or characteristic curve, see Fig 2.

This component of the circuit breaker is constructed using a coil or solenoid, which is designed to operate the tripping mechanism when the overcurrent reaches a set magnitude. This magnetic component is specifically designed to deal with fault current. As can be seen from the graphs, (Fig 2) the letter B, C, or D represents a multiple of I_n. When the current rises to this multiple value, the magnetic trip operates instantaneously to open the contacts.

Conclusion

Please note this article is only intended as a brief overview of some of the changes introduced into Appendix 4 by amendment 1 of the 17th edition of the wiring regulations. Circuits must be designed that are fit for purpose and suitable for the load they are intended to supply. They should be correctly designed in accordance with BS 7671.

Chapter 43 deals with protection against overcurrent and also thermal constraints, chapter 42 has requirements for protection against thermal effects, chapter 41 deals with protection against electric shock and gives the disconnection times that must be met whilst section 525 deals with voltage drop. In addition, sections 526 and 512.1.5 have requirements for the temperature of conductors connected to equipment terminals. Appendix 4 gives tabulated current carrying capacity and voltage drop for cables.

All these areas need to be taken into account when determining the cable size for a particular circuit. For more information refer to Amendment 1 of BS 7671:2008.

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