

EUROPEAN STANDARD
NORME EUROPÉENNE
EUROPÄISCHE NORM

DRAFT
prEN 50343

April 2012

ICS 45.060.01

Will supersede EN 50343:2003

English version

**Railway applications -
Rolling stock -
Rules for installation of cabling**

Applications ferroviaires -
Matériel roulant -
Règles d'installation du câblage

Bahnanwendungen -
Fahrzeuge -
Regeln für die Installation von elektrischen
Leitungen

This draft European Standard is submitted to CENELEC members for CENELEC enquiry.
Deadline for CENELEC: 2012-09-07.

It has been drawn up by CLC/SC 9XB.

If this draft becomes a European Standard, CENELEC members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

This draft European Standard was established by CENELEC in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CENELEC member into its own language and notified to the CEN-CENELEC Management Centre has the same status as the official versions.

CENELEC members are the national electrotechnical committees of Austria, Belgium, Bulgaria, Croatia, Cyprus, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and the United Kingdom.

Recipients of this draft are invited to submit, with their comments, notification of any relevant patent rights of which they are aware and to provide supporting documentation.

Warning : This document is not a European Standard. It is distributed for review and comments. It is subject to change without notice and shall not be referred to as a European Standard.

CENELEC

European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

Management Centre: Avenue Marnix 17, B - 1000 Brussels

1

Contents

2	Foreword	5
3	1 Scope	6
4	2 Normative references	6
5	3 Terms and definitions	8
6	4 Abbreviations	10
7	5 Technical requirements	10
8	5.1 General requirements.....	10
9	5.2 Selection of type and size of cables.....	10
10	5.3 Bundling of cables.....	17
11	5.4 Flexibility of cables.....	18
12	5.5 Minimum cross-sectional area of conductors.....	18
13	5.6 Use of green and yellow colour.....	18
14	5.7 Bending radii and other mechanical requirements.....	19
15	5.8 Re-termination.....	20
16	5.9 Busbars.....	20
17	5.10 Connections to busbars.....	21
18	5.11 Separation of cables with different voltage levels for safety reasons.....	21
19	5.12 Provisions for refurbishment and maintenance, including inspection and repair.....	22
20	5.13 Fire prevention, cable laying and cabling behaviour in case of fire.....	23
21	5.14 Provision of spares.....	24
22	5.15 Requirements for fixing.....	24
23	5.16 Clearances and creepage distances.....	25
24	5.17 Requirements for electrical terminations.....	25
25	5.18 Use of heat-shrinkable sleeves.....	28
26	5.19 Connections for return current.....	28
27	5.20 Storage of cables.....	28
28	5.21 Cable conduits.....	29
29	5.22 Electrical bolted connections.....	29
30	6 EMC requirements	31
31	6.1 General.....	31
32	6.2 Cable categories.....	31
33	6.3 Separation of cables.....	32
34	6.4 Return conductor.....	33
35	6.5 Use of conductive structure.....	33
36	6.6 Shielding and earthing.....	33
37	6.7 Supply connection from battery.....	33
38	6.8 Databus lines.....	33
39	7 Marking for identification	34
40	7.1 General.....	34
41	7.2 Marking for identification of cables and busbars.....	34
42	7.3 Marking for identification of terminal blocks, individual terminals, plugs and sockets.....	35
43	7.4 Marking of insulators.....	35
44	7.5 Marking for warning against electrical shock.....	35
45	7.6 Marking using heat-shrinkable sleeves.....	35
46	8 Testing	35
47	8.1 General concerning testing.....	35
48	8.2 Electrical insulation tests.....	36
49	Annex A (normative) Cable sizing – Calculation of load current under short time load conditions	40
50		
51	Annex B (informative) Cable sizing – Examples of current ratings	42
52	Annex C (normative) Cable sizing – Calculating current ratings for temperature classes other than 90 °C	44
53		

54	Annex D (normative) Cable sizing – Correction factor k_1 for expected ambient temperature	45
55	Annex E (normative) Cable sizing – Prediction of cable lifetime	46
56	Annex F (informative) Cable sizing – Calculation examples	47
57	Annex G (informative) Terminations	48
58	G.1 Methods of terminating cables	48
59	G.2 Tensile strenght.....	54
60	Annex H (normative) Tests on marking when using heat-shrinkable sleeves	56
61	H.1 General.....	56
62	H.2 Preparation of specimens	56
63	H.3 Testing of specimens	57
64	H.4 Result of test	57
65	Annex I (informative) Effects of the number of earth connections to a cable screen	58
66	Annex J (informative) Differences of electrochemical potentials between some conductive	
67	materials	59
68	Annex K (informative) Locations on board rolling stock to be distinguished	60
69	Bibliography	62
70		
71	Figures	
72	Figure 1 – Example of short circuit condition where cable size will have influence on protection device	
73	behaviour	11
74	Figure 2 – Cable grouping and installation conditions.....	16
75	Figure 3 – Locations in rolling stock, concerning use of minimum cross-sectional areas for	
76	conductors	18
77	Figure 4 – Definition of internal bending radius.....	19
78	Figure 5 – Examples of mechanical protecting of cabling.....	20
79	Figure 6 – Separation of cables by required distance: $D > 2 d$ and $D > 0,1 \text{ m}$	22
80	Figure 7 – Examples of separation of cables by barriers or by insulation	22
81	Figure 8 – Dimensions for calculating the effective area of a contact (example for a cable lug).....	27
82	Figure 9 – Example of sequence order of elements belonging to a bolted connection (nut)	30
83	Figure 10 – Example of sequence order of elements belonging to a bolted connection (bolt)	31
84	Figure 11 – Examples of cable or plug constructions where identification is done by configuration.....	34
85	Figure K.1 – Distinguishing locations on board rolling stock	60
86		

87 **Tables**

88	Table 1 – Modification factor k_5 for individual conductors within a multi core cable	14
89	Table 2 – Modification factor k_2 for installation type (grouping and installation conditions)	15
90	Table 3 – Selection of cable conductor size on the basis of rating of protection device	17
91	Table 4 – Minimum internal bending radii R for static applications	19
92	Table 5 – Example of division of cables into three categories for safety reasons	21
93	Table 6 – Cable categories with respect to EMC	32
94	Table 7 – Minimum distances between cables of different EMC categories.....	32
95	Table 8 – Standard letter codes	34
96	Table 9 – Test voltages according to on-board voltages	38
97	Table 10 – Test voltages according to supply line voltages	38
98	Table A.1 – Modification factor k_4	41
99	Table B.1 – Examples of current ratings for standard wall cables, with 90 °C maximum conductor	
100	operating temperature	43
101	Table C.1 – Factor k^* , used when comparing current ratings for 90 °C maximum conductor	
102	operating temperature with other temperature classes	44
103	Table D.1 – Modification factor k_1	45
104	Table E.1 – Examples of values of correction factor k_3 to allow for decrease in predicted cable	
105	lifetime	46
106	Table G.1 – Methods of terminating cables – Conductor side	48
107	Table G.2 – Methods of terminating cables – Terminal side – Crimp connections.....	49
108	Table G.3 – Methods of terminating cables – Terminal side – Screwed and bolted connection	51
109	Table G.4 – Methods of terminating cables – Terminal side – Connection by clamping	52
110	Table G.5 – Methods of terminating cables – Terminal side – Connection by insulation displacement	
111	or penetration	53
112	Table G.6 – National standards for termination methods	54
113	Table G.7 – Tensile strength for crimp connections	55
114	Table H.1 – Preparation of heat-shrinkable sleeve for test of marking quality.....	56
115	Table I.1 – Effects of shielding	58
116	Table J.1 – Differences of electrochemical potentials between some conductive materials (in mV).....	59

117

118

Foreword

119 This document [prEN 50343:2012] has been prepared by CLC/SC 9XB "Electromechanical material on
120 board rolling stock".

121 This document is currently submitted to the Enquiry.

122 This document will supersede EN 50343:2003.

123 prEN 50343:2012 includes the following significant technical changes with respect to EN 50343:2003:

124 – references to other standards updated and harmonized;

125 – factor k_5 concerning sizing of multi core cables introduced;

126 – factor k_2 detailed, see Table 2;

127 – short time load detailed;

128 – mechanical aspects detailed;

129 – separation of cables due to safety reasons and EMC reasons harmonized;

130 – details added and changed concerning electrical and mechanical requirements for electrical terminations;

131 This document has been prepared under a mandate given to CENELEC by the European Commission
132 and the European Free Trade Association, and supports essential requirements of EU Directive(s).

<https://standards.iteh.ai/catalog/standards/sist/c94d4ed6-3d6b-4451-89fc-fc63b3dbb104/sist-en-50343-2014>

133 1 Scope

134 This European Standard specifies requirements for the installation of cabling on railway vehicles and
135 within electrical enclosures on railway vehicles, including magnetic levitation trains and trolley buses.

136 NOTE With respect to trolley buses, this European Standard applies to the whole electric traction system, including current
137 collecting circuits, power converters and the respective control circuits. The installation of other circuits is covered by street vehicle
138 standards for example those for combustion driven buses.

139 This European Standard covers cabling for making electrical connections between items of electrical
140 equipment, including cables, busbars, terminals and plug/socket devices. It does not cover special effect
141 conductors like fibre optic cables or hollow conductors (waveguides).

142 The material selection criteria given here are applicable to cables with a copper conductor.

143 This European Standard is not applicable to the following:

- 144 – special purpose vehicles, such as track-laying machines, ballast cleaners and personnel carriers;
- 145 – vehicles used for entertainment on fairgrounds;
- 146 – vehicles used in mining;
- 147 – electric cars;
- 148 – funicular railways.

149 As the field of cabling in rolling stock is also dealt with in the cable makers' standard, references are made
150 to EN 50264 series, EN 50306 series, EN 50382 series and EN 50355.

151 This European Standard applies in conjunction with the relevant product and installation standards.
152 Stricter requirements than those given in this European Standard may be necessary.

<https://standards.iteh.ai/catalog/standards/sist/c94d4ed6-3d6b-4451-89fc->

153 2 Normative references

154 The following documents, in whole or in part, are normatively referenced in this document and are
155 indispensable for its application. For dated references, only the edition cited applies. For undated
156 references, the latest edition of the referenced document (including any amendments) applies.

157 CEN(CLC)/TS 45545 (all parts), *Railway applications – Fire protection on railway vehicles*

158 CEN/TS 45545-1:2009, *Railway applications – Fire protection on railway vehicles – Part 1: General*

159 CLC/TS 45545-5:2009, *Railway applications – Fire protection on railway vehicles – Part 5: Fire safety*
160 *requirements for electrical equipment including that of trolley buses, track guided buses and magnetic*
161 *levitation vehicles*

162 EN 50121-3-1, *Railway applications – Electromagnetic compatibility – Part 3-1: Rolling stock – Train and*
163 *complete vehicle*

164 EN 50121-3-2, *Railway applications – Electromagnetic compatibility – Part 3-2: Rolling stock – Apparatus*

165 EN 50124-1, *Railway applications – Insulation coordination – Part 1: Basic requirements – Clearances*
166 *and creepage distances for all electrical and electronic equipment*

167 EN 50125-1, *Railway applications – Environmental conditions for equipment – Part 1: Equipment on board*
168 *rolling stock*

169 EN 50153, *Railway applications – Rolling stock – Protective provisions relating to electrical hazards*

- 170 EN 50200, *Method of test for resistance to fire of unprotected small cables for use in emergency circuits*
- 171 EN 50215:2009, *Railway applications – Rolling stock – Testing of rolling stock on completion of*
172 *construction and before entry into service*
- 173 EN 50264-1, *Railway applications – Railway rolling stock power and control cables having special fire*
174 *performance – Part 1: General requirements*
- 175 EN 50264-2-1, *Railway applications – Railway rolling stock power and control cables having special fire*
176 *performance – Part 2-1: Cables with crosslinked elastomeric insulation – Single core cables*
- 177 EN 50264-2-2, *Railway applications – Railway rolling stock power and control cables having special fire*
178 *performance – Part 2-2: Cables with crosslinked elastomeric insulation – Multicore cables*
- 179 EN 50264-3-1, *Railway applications – Railway rolling stock power and control cables having special fire*
180 *performance – Part 3-1: Cables with crosslinked elastomeric insulation with reduced dimensions – Single*
181 *core cables*
- 182 EN 50264-3-2, *Railway applications – Railway rolling stock power and control cables having special fire*
183 *performance – Part 3-1: Cables with crosslinked elastomeric insulation with reduced dimensions –*
184 *Multicore cables*
- 185 EN 50306-1, *Railway applications – Railway rolling stock cables having special fire performance – Thin*
186 *wall – Part 1: General requirements*
- 187 EN 50306-2, *Railway applications – Railway rolling stock cables having special fire performance – Thin*
188 *wall – Part 2: Single core cables*
- 189 EN 50306-3, *Railway applications – Railway rolling stock cables having special fire performance – Thin*
190 *wall – Part 3: Single core and multicore cables (pairs, triples and quads) screened and thin wall sheathed*
- 191 EN 50306-4, *Railway applications – Railway rolling stock cables having special fire performance – Thin*
192 *wall – Part 4: Multicore and multipair cables standard wall sheathed*
- 193 EN 50362, *Method of test for resistance to fire of larger unprotected power and control cables for use in*
194 *emergency circuits*
- 195 EN 50382-1, *Railway applications – Railway rolling stock high temperature power cables having special*
196 *fire performance – Part 1: General requirements*
- 197 EN 50382-2, *Railway applications – Railway rolling stock high temperature power cables having special*
198 *fire performance – Part 2: Single core silicone rubber insulated cables for 120 °C or 150 °C*
- 199 EN 50467, *Railway applications – Rolling stock – Electrical connectors, requirements and test methods*
- 200 EN 50553 ¹⁾, *Railway applications – Requirements for running capability in case of fire on board of rolling*
201 *stock*
- 202 EN 60228, *Conductors of insulated cables (IEC 60228)*
- 203 EN 60684-3-212, *Flexible insulating sleeving – Part 3: Specifications for individual types of sleeving –*
204 *Sheet 212: Heat-shrinkable polyolefin sleeveings (IEC 60684-3-212)*
- 205 EN 60684-3-216, *Flexible insulating sleeving – Part 3: Specifications for individual types of sleeving –*
206 *Sheet 216: Heat-shrinkable, flame-retarded, limited-fire hazard sleeving (IEC 60684-3-216)*
- 207 EN 60684-3-217 ²⁾, *Flexible insulating sleeving. Part 3: Specifications for individual types of sleeving –*
208 *Sheet 217: Heat-shrinkable polyolefin sleeving, flame retarded shrink ratio 3:1 (IEC 60684-3-217)*

1) To be published.

2) EN 60684-3-217 is superseded by EN 60684-3-212:2006.

- 209 EN 60684-3-271, *Flexible insulating sleeving – Part 3: Specifications for individual types of sleeving –*
 210 *Sheet 271: Heat-shrinkable elastomer sleeving, flame retarded, fluid resistant, shrink ratio 2:1*
 211 *(IEC 60684-3-271)*
- 212 EN 61180-1, *High-voltage test techniques – Part 1: Definitions, test and procedure requirements*
 213 *(IEC 61180-1)*
- 214 HD 60364-5-54:2011, *Low-voltage electrical installations – Part 5-54: Selection and erection of electrical*
 215 *equipment – Earthing arrangements and protective conductors (IEC 60364-5-54:2011)*

216 3 Terms and definitions

217 For the purposes of this document, the following terms and definitions apply.

218 3.1

219 **cable**

220 assembly consisting of

- 221 - one or more cores (screened or unscreened),
- 222 - their individual covering(s) (if any),
- 223 - assembly protection (if any),
- 224 - screen(s) (if any),
- 225 - sheath (if any)

226 [SOURCE: IEC 60050-461, 461-06-01, mod.]

227 3.2

228 **conductor (of a cable)**

229 part of a cable which has the specific function of carrying current

230 [SOURCE: IEC 60050-461, 461-01-01]

231 3.3

232 **core**

233 assembly comprising a conductor with its own insulation (and screens if any)

234 [SOURCE: IEC 60050-461, 461-04-04]

235 3.4

236 **solid conductor**

237 conductor consisting of a single wire

238 [SOURCE: IEC 60050-461, 461-01-06, mod.]

239 3.5

240 **stranded conductor**

241 conductor consisting of a number of individual wires or strands all or some of which generally have a
 242 helical form

243 [SOURCE: IEC 60050-461, 461-01-07, mod.]

244 3.6

245 **busbar**

246 conductor consisting of a rigid metal profile

- 247 **3.7**
248 **screen (of a cable)**
249 conducting layer(s) having the function of control of the electro magnetic field within the cable and/or to
250 protect the cable from external electro magnetic influences
251 [SOURCE: IEC 60050-461, 461-03-01, mod.]
- 252 **3.8**
253 **bundle**
254 group of cables tied together
- 255 **3.9**
256 **bolted connection**
257 connection in which the pressure to the conductor is applied by bolting
258 [SOURCE: IEC 60050-461, 461-19-05]
- 259 **3.10**
260 **crimp**
261 cable termination in which a permanent connection is made by applying pressure, inducing the
262 deformation or reshaping of a barrel part of the termination around the conductor
263 [SOURCE: IEC 60050-461, 461-19-01, mod.]
- 264 **3.11**
265 **spring-clamp connection**
266 terminal connection in which the pressure between the conductor and terminal is applied by a spring
- 267 **3.12**
268 **penetration (connection)**
269 terminal connection in which the contact with the conductor is achieved by jaws which penetrate the
270 insulation
- 271 **3.13**
272 **plug**
273 connector intended to be coupled at the free end of an insulated conductor or cable, to be inserted into a
274 matching socket, or readily removed when required
- 275 **3.14**
276 **socket**
277 connector intended to be mounted on a rigid surface and to hold a matching plug, such that the
278 conductors contained within the socket make electrical contact individually with those in the plug
- 279 **3.15**
280 **heat-shrinkable sleeve**
281 tube that on exposure to heat during installation, will at a critical temperature, permanently reduce in
282 diameter, while increasing in wall thickness
- 283 **3.16**
284 **manufacturer**
285 organisation that has the responsibility for the supply of vehicle(s), equipment or groups of equipment to
286 the purchaser
- 287 **3.17**
288 **purchaser**
289 organisation that orders the vehicle or equipment or groups of equipment and has the responsibility for
290 direct negotiations with the manufacturer

291 **4 Abbreviations**

292 For the purposes of this document, the following abbreviations apply.

293 EMC Electromagnetic compatibility

294 CSA Cross sectional area

295 **5 Technical requirements**

296 **5.1 General requirements**

297 Cables and installation materials shall be type tested, selected for size and installed so as to be suitable
298 for their function under their operating conditions. Size and installation of cables (or busbars) shall take
299 into account the particular stresses to be expected in rolling stock. The materials used and methods of
300 cabling shall be such as to prevent strain or chafing and excessive lengths of unsupported cable shall be
301 avoided.

302 Cables on rolling stock shall not be used for any purpose other than for transmission, distribution and
303 collection of electrical energy, electrical controls or monitoring systems. All components of cabling shall be
304 selected, installed, protected, used and maintained so as to prevent danger (e.g. electrical or fire hazard,
305 EMC problems).

306 The electrical connections shall be made in such a way that they can not be unintentionally disconnected
307 or interrupted during service by thermal effects, dynamic loads as shock, vibration, car-body motions, etc.
308 that are to be expected.

309 Where ambient conditions are considered, EN 50125-1 shall apply.

310 For protection against electrical hazard, the cabling installed shall be in accordance with EN 50153.

311 **5.2 Selection of type and size of cables**

312 **5.2.1 General**

313 When selecting cables or busbars the expected operating conditions should be taken into account. These
314 should include but are not limited to the following parameters:

- 315 – voltage;
- 316 – current;
- 317 – overload current;
- 318 – voltage drop;
- 319 – short circuit current;
- 320 – shape and frequency of current;
- 321 – fusing characteristic of the protection device;
- 322 – grouping of cables;
- 323 – ambient temperature and temperature due to load current;
- 324 – methods of installation;
- 325 – predicted cable lifetime;

- 326 – presence of rain or steam or snow or accumulation of condensing water;
 327 – presence of corrosive, polluting or damaging substances;
 328 – mechanical stresses;
 329 – radiation such as sunlight.

330 Consideration should be given to the expected lifetime of the cabling compared with the expected lifetime
 331 of the vehicle.

332 The cable type (i.e. cable family) shall be selected in accordance with EN 50264 series, EN 50382 series
 333 or EN 50306 series etc, as applicable.

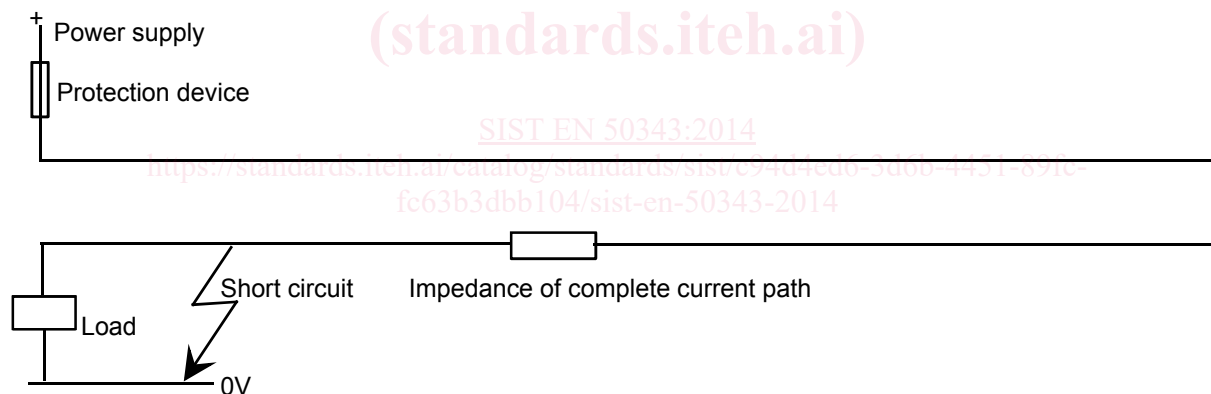
334 Once the cable type has been selected, the selection of conductor size when the cable is intended for
 335 power distribution shall be based on either load current and current carrying capacity calculated in
 336 accordance with 5.2.3, or based on protection device size in accordance with 5.2.4.

337 Short circuit conditions should additionally be checked according to HD 60364-4-43 and 5.2.7.
 338 Recommended short circuit ratings for rolling stock cables are given in EN 50355. Short circuit conditions
 339 and overload conditions should be checked with respect to the fusing characteristic of the protection
 340 device and the resistance of the chosen cable. See example in Figure 1.

341 NOTE 1 This short circuit or overload case should be checked according to:

342 Normal load < nominal switching level of protection device < current carrying capacity of the cable

343 (I_{corr} , see definition in 5.2.3 b).



344

345 **Figure 1 – Example of short circuit condition**
 346 **where cable size will have influence on protection device behaviour**

347 The cross-sectional area of any conductor shall be not less than the value specified in 5.5.

348 Only cabling which conforms to the fire safety requirements specified in Clause 6 of
 349 CEN/TS 45545-1:2009 and CLC/TS 45545-5:2009 shall be used.

350 NOTE 2 The number of different types of cables installed on any one type of vehicle should be minimized for practical reasons.

351 5.2.2 Selection of cable size for control cables

352 Control cables, which are intended to carry control signals only, shall have a minimum conductor cross-
 353 sectional area as specified in 5.5. This is also valid if the load current would make a smaller cross-
 354 sectional area possible.

355 NOTE It is not necessary for the conductor size of these cables to be selected according to 5.2.3.

356 **5.2.3 Selection of cable size for cables for power distribution, on the basis of continuous load**
 357 **current**

358 This subclause specifies a method for calculation of continuous maximum load current, of time duration
 359 longer than 5 s, of different cable sizes dependent on their method of installation and ambient
 360 temperature, to enable cables to be selected so as to ensure that the predicted lifetime is achieved.

361 For short time current load, up to 5 s, see 5.2.7.

362 The continuous maximum conductor temperature for the cable types defined in the various parts of
 363 EN 50264, EN 50306 and EN 50382 is either 90 °C, 105 °C and 120 °C or 150 °C. This is based either on
 364 proven experience and reliability over many years or in the case of newer, less well defined, insulations
 365 upon an acceptance test, using long-term thermal endurance ageing to demonstrate a lifetime of at least
 366 20 000 h at 110 °C, 125 °C and 140 °C or 170 °C respectively (i.e. 20 °C above the continuous rating).
 367 Data from this thermal testing can, with care, be extrapolated to the conductor temperature to provide a
 368 predicted lifetime of the cable when continuously loaded. This predicted lifetime may be used in
 369 conjunction with the known duty cycle of the vehicle, and its predicted time out of service, to estimate the
 370 ability of the cable to function reliably for the predicted lifetime of the whole vehicle.

371 NOTE 1 Because the cable standards allow a variety of solutions for insulation type, it is important to confirm lifetime
 372 extrapolations with the cable manufacturer.

373 NOTE 2 A predicted lifetime of cable of 100 000 h may be used as a theoretical basis value.

374 NOTE 3 This subclause only deals with thermal degradation of insulation material and it should be noted that mechanical
 375 stresses (wear, etc.) and other environmental factors (such as presence of fluids such as cleaning detergents, aggressive
 376 atmosphere) may be the limiting factor determining predicted cable lifetime.

377 For cables intended for power distribution, the cable size shall be selected on the basis of the load current
 378 and the current carrying capacity in accordance with the following procedure (i.e. the three steps a), b)
 379 and c)).

380 a) The load current

381 The load current I_{load} , in amperes (A) which a cable has to carry for sustained periods during normal
 382 service shall be a basic value for cable sizing.

383 When the circuit(s) being supplied by the cable is in continuous or sustained cyclic operation, I_{load}
 384 shall be calculated according to the following formula:

$$385 \quad I_{\text{load}} = \sqrt{\frac{1}{t_1} \int i^2 dt}$$

386 where

387 t_1 is the duration of a typical duty cycle during service, in minutes (min);

388 i is the instantaneous current – including overload, if any - in amperes (A).

389 NOTE 4 For continuous direct current operation, the above formula has the simple form $I_{\text{load}} = i$.

390 When operation is not continuous or sustained cyclic, I_{load} shall be calculated according to Annex A.

391 b) The current carrying capacity

392 The permissible continuous current carrying capacity I_{cable} in amperes (A) of a single-core cable
 393 being operated in free air shall be another basic value for cable sizing. A particular value of I_{cable} is
 394 valid for a particular reference ambient temperature T_{ref} and for a particular maximum conductor
 395 temperature in service, $T_{\text{c(max)}}$.

396 The values I_{cable} , T_{ref} and $T_{\text{c(max)}}$ to be used, shall be those provided by the cable manufacturer,
397 however, some examples are presented in Annex B.

398 I_{cable} for maximum conductor temperatures other than $T_{\text{c(max)}} = 90\text{ °C}$, shall be calculated according
399 to Annex C.

400 The current carrying capacity of the cable in service, I_{corr} , in amperes (A) shall be calculated from
401 I_{cable} using correction factors to take into account the expected ambient temperature, the installation
402 type, etc., in accordance with the following formula.

$$403 \quad I_{\text{corr}} = I_{\text{cable}} \times k_1 \times k_2 \times k_3 \times k_4 \times k_5$$

404 where

405 k_1 is a correction factor for the expected ambient temperature. It shall be calculated according
406 to the following formula:

$$407 \quad k_1 = \sqrt{\frac{T_{\text{c(max)}} - T}{T_{\text{c(max)}} - T_{\text{ref}}}}$$

408 where

409 $T_{\text{c(max)}}$ is the maximum conductor temperature, in degrees Celsius (°C), in service, which
410 will allow the predicted lifetime of the cable to be achieved;

411 T is the estimated value of the actual ambient temperature, in degrees Celsius (°C)
412 during operation, on the outside of the bundle or of the tube - if any. T is an
413 average value;

414 T_{ref} is the reference ambient temperature, in degrees Celsius (°C), for which the
415 I_{cable} value is valid.

416 Examples of k_1 values are given in Table D.1.

417 k_2 is a correction factor for installation type (grouping and installation conditions).

418 Values for k_2 given in Table 2 shall be used. Interpolation between the different numbers of cables in
419 Table 2 is allowed.

420 k_3 is a correction factor to allow for a decrease in predicted cable lifetime, calculated according to
421 the formula in Annex E. In all cases where the standard predicted cable lifetime shall be used, the
422 value of k_3 shall be 1,0.

423 k_4 is a correction factor to take into account short time current when operation is not continuous,
424 calculated according to the procedure in Annex A. When operation is continuous, the value of k_4
425 shall be 1,0.

426 k_5 is a correction factor for multi core cables only; the correction factor k_5 is applicable for each
427 individual conductor within a multi core cable. Values for k_5 are given in Table 1. Interpolation
428 between the different number of cores in Table 1 is allowed. When single core cables are used, the
429 value of k_5 shall be 1,0.