COUDOINT

# Edgewound Resistors

## Hardware Reference

Document 1101023 - Edition June 2009

# Table of Contents



COUDOINT

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# 1 General Description

Edgewound resistors are characterized by :

- **high currents**: continuous rated currents up to **103 Amps**, in short time duty up to **1650 Amps**
- **power ratings** up to **3300 watts** in continuous duty and natural-air cooling
- **low ohmic values** from **0.018 ohm**
- **high energy absorption** during instantaneous discharges up to **527 kilojoules**

**Series and models**:

Coudoint standard edgewound resistors are offered in the TOFIL Series and BC Series. Other special series and models are available as well.

Resistor assemblies can be supplied as open frames, available to OEMs for mounting in their own enclosure, or in indoor/outdoor enclosures according to a specified IP level.

**The Coudoint technical sales department is at your disposal to help you choose or define a solution to meet your needs for of resistive loads.**

**Description**: Edgewound resistors are constructed with:

- a coil of edgewound heavy resistance alloy ribbon,
- grooved insulators supporting this coil,
- terminals which are welded to the resistance element,
- optional intermediary terminals: fixed (welded) or adjustable,
- mounting hardware : brackets, threaded rod, etc.

**TOFIL and BC Series**

- the two series use the same resistance coils and have overall, for an equal number of turns, the **same electrical and thermal characteristics**
- they differ in in the mechanical design, with an insulated support of the coil made with:
  - for the TOFIL resistors: a one-piece grooved ceramic tube
  - for the BC resistors: toothed ceramic insulators supported by a zinc-plated steel mounting bar
- the two series share:
  - a set of **21 types (lines) of resistance ribbon** using 4 different types of alloy
  - a set of **7 standard models** with 7 standard coil lengths: TOFIL-1 to TOFIL-7 and BC-1 to BC-7
- beyond this standard:
  - 2 longer standard BC models are available: BC-8 and BC-9
  - a longer TOFIL ceramic core can be used for designing resistors beyond the TOFIL-7 model
- **every ohmic value can be supplied in the range of** feasibility in the **TOFIL (0.018 to 3.9 Ω) and BC (0.018 to 5.1 Ω)** series.
- TOFIL and BC resistors are ROHS compliant

**Other series and models, edgewound resistor assemblies** :

We can supply other series --such as ZOFIL series for traction (railway) applications, etc.-- and models than those found in this document, with special characteristics (reduced tolerances at ambient or in the full temperature range, multiple resistors on the same structure, etc.). Please contact us.

Old models (M17, etc.) can be supplied depending on the availability of the components. If necessary, we can suggest a replacement solution.

When a single resistor cannot fulfill the requirement, we can offer resistor assemblies - open frame constructions or enclosures - with resistors from different series.

**Temperature rise**:

All data are given here for a resistor in horizontal position, alone, in free-air cooling conditions.

For a resistor assembly, as an open frame or in an enclosure, or in forced-air cooling, Please contact us.

**Tolerances**:

**Standard tolerance on the ohmic value is ± 5 %** at ambient temperature (25°C) - for more than 10 turns.

Reduced tolerances are available on request.

The variation of the ohmic value with the temperature depends on the type of alloy used for the resistance coil.

All data provided in this document are approximate values because of the component and process tolerances. Contractual values are only those mentioned on the commercial document for each specific proposal.

# 2 Product Selection Guide

The table below may be used to select a **TOFIL** or **BC** edgewound resistor for a given requirement: select the resistance alloy, then the cross-sectional size of the ribbon. Then, with the tables on the following pages, select the model corresponding to the required ohmic value or energy level. If a solution cannot be found, a resistor assembly may be required.

**An easy way to select a resistor is to describe what you need to us and we will suggest an optimized solution.**

| **Selection of the alloy** according to :<br>- the general criteria regarding the application<br>- the ohmic value variation ΔR vs. temperature between ambient and nominal values | | **Ribbon selection**<br>(= number of the line) meeting the required current level :<br>- in continuous duty: $I_{NOM}$<br>- in short time duty: $I_{INT}$ (see p.12) | | | **Selection of the model** meeting:<br>- the required ohmic value<br>- the required energy in instantaneous discharge (p. 11)<br>with tables on pages 7 to 9 | |
|---|---|---|---|---|---|---|
| General criteria regarding the application | ΔR for Δ=100°C | Line N° | $I_{NOM}$ (A) | $I_{INT}$ Max. (A) | Ohmic values | Instantaneous energy |
| **Alloy A: "Silver nickel"**<br>- very low ohmic values<br>- high currents<br>- good stability over temperature | +0.8 % | **Line 1** | 103 | 1,650 | **0.018 to 0.21 Ω** | 46 to 534 kJ |
| | | **Line 2** | 93 | 1,300 | **0.022 to 0.26 Ω** | 39 to 451 kJ |
| | | **Line 3** | 84 | 1,000 | **0.028 to 0.33 Ω** | 29 to 338 kJ |
| **Alloy B: "Stainless steel"**<br>- cost advantage<br>- poor stability over temperature<br>- good overload capacity | +10 % | **Line 4** | 78 | 1,200 | **0.041 to 0.48 Ω** | 59 to 689 kJ |
| | | **Line 5** | 59 | 800 | **0.057 to 0.67 Ω** | 37 to 429 kJ |
| | | **Line 6** | 52 | 600 | **0.077 to 0.89 Ω** | 27 to 313 kJ |
| | | **Line 7** | 42 | 400 | **0.113 to 1.32 Ω** | 19 to 216 kJ |
| | | **Line 8** | 36 | 310 | **0.147 to 1.72 Ω** | 14 to 164 kJ |
| **Alloy C: "Chromium-Aluminum"**<br>- used as a standard<br>- good stability over temperature<br>- good overload capacity | +1 % | **Line 9** | 42 | 500 | **0.113 to 1.32 Ω** | 27 to 317 kJ |
| | | **Line 10** | 36 | 375 | **0.147 to 1.72 Ω** | 21 to 247 kJ |
| | | **Line 11** | 32 | 285 | **0.196 to 2,28 Ω** | 16 to 183 kJ |
| | | **Line 12** | 29 | 235 | **0.22 to 2.56 Ω** | 13 to 151 kJ |
| | | **Line 13** | 24 | 165 | **0.32 to 3.73 Ω** | 9 to 109 kJ |
| | | **Line 14** | 21 | 120 | **0.44 to 5.12 Ω** | 7 to 76 kJ |
| **Alloy D: "Nickel-Chromium"**<br>- good stability over temperature<br>- good overload capacity<br>- very good resistance to corrosion<br>- low amount of iron (magnetic effect)<br>- for demanding applications : railway, marine applications, etc. | +1,8 % | **Line 15** | 52 | 750 | **0.077 to 0.89 Ω** | 44 to 513 kJ |
| | | **Line 16** | 42 | 510 | **0.113 to 1.32 Ω** | 30 to 345 kJ |
| | | **Line 17** | 36 | 400 | **0.147 to 1.72 Ω** | 23 to 269 kJ |
| | | **Line 18** | 32 | 290 | **0.196 to 2.28 Ω** | 17 to 199 kJ |
| | | **Line 19** | 29 | 250 | **0.22 to 2.56 Ω** | 14 to 165 kJ |
| | | **Line 20** | 24 | 170 | **0.32 to 3.73 Ω** | 10 to 119 kJ |
| | | **Line 21** | 21 | 120 | **0.44 to 5.12 Ω** | 7 to 83 kJ |

# 3 TOFIL and BC Series

## 3.1 General Description

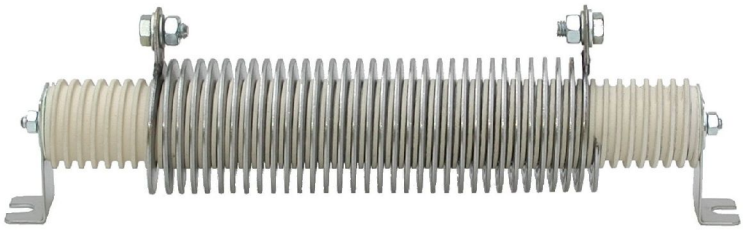
The resistors in the **TOFIL and BC series use the same edgewound resistance coils**, with a higher maximum number of turns for the BC series ( BC-8: 93 turns and BC-9: 105 turns) than the TOFIL series (84 turns maximum ).

**The electrical and thermal characteristics of the resistors are the same** for a given line and number of turns .

The terminals and optional intermediary lugs are the same in the two series,

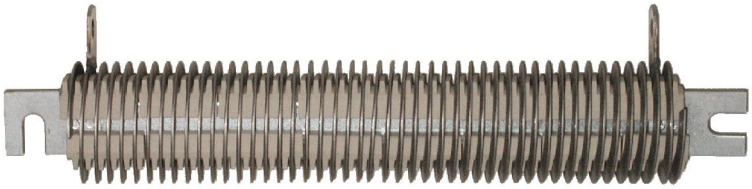
The difference between the resistors in the two series resides in the mechanical structure supporting the resistance coil and then in their dimensions:

– The TOFIL resistors are constructed with a one-piece grooved ceramic tube:



The length of the ceramic tube, and of the resistor, can be adapted to match the required ohmic value.

– The BC resistors use toothed ceramic insulators supported by a zinc plated steel mounting bar. The bar is slotted at both ends:



The length of the BC resistors are the same as in the standard model, for which the mounting bars have been designed to match the possible combinations of the ceramic jumpers, and only 9 sizes are available.

## 3.2 Electrical and Thermal Specifications

### 3.2.1 Resistance ribbons

Twenty_one types of resistance ribbon are used in the standard models. Each type is designated by the corresponding line number in the Product Selection Guide - line 1 to line 21 - and is characterized by the type of the alloy - in the 4 possibilities - and by the cross-sectional size of the resistance ribbon.

- **Alloys**: The 4 types of alloys used for the standard models are:
  - **Alloy A: Silver-nickel**
    - used for lines 1 to 3
    - nominal composition: copper (~63%), zinc (~22%) and nickel (~15%)
    - resistivity: 31 $\Omega.mm^2.m^{-1}$ at 25°C
    - coefficient of resistivity (vs temperature) lower than 80 ppm/°C.

    This alloy is suitable when low ohmic values, high currents and a low temperature coefficient of resistance are required.
    This alloy is corrosible when used in chemical industry.
  - **Alloy B: Stainless steel**
    - used for lines 4 to 8
    - nominal composition: iron (~72%), nickel (~19%) and chromium (~9%)

- resistivity: 73 Ω.mm$^2$.m$^{-1}$ at 25°C
- coefficient of resistivity (vs. temperature): ~ 1000 ppm/°C.

This alloy is suitable for applications where cost is the primary factor and where a low temperature coefficient of resistance is not required.

- **Alloy C: Chromium-aluminum**
  - used for lines 9 to 14
  - nominal composition: iron (~80%), chromium (~13%), aluminum (~5%) and manganese (~0.8%)
  - resistivity: 122 Ω.mm$^2$.m$^{-1}$ at 25 °C
  - coefficient of resistivity (vs. temperature) lower than 100 ppm/°C.

  This alloy is used as a standard because of its very good cost/performance ratio, and especially the stability of the ohmic value versus temperature.

- **Alloy D: Nickel-chromium**
  - used for lines 15 to 21
  - nominal composition: nickel (~60%), iron (~25%) and chromium (~15%)
  - resistivity: 112 Ω.mm$^2$.m$^{-1}$ at 25°C
  - coefficient of resistivity (vs. temperature) lower than 180 ppm/°C.

  This alloy performs well and has a particularly strong resistance to corrosion and a very stable resistivity versus temperature. Due to the low amount of iron, it is not very sensitive to the magnetic susceptibility effect . For these reasons, it is usually selected for the most demanding applications such as railway and marine applications.

## Lines of resistance ribbon:

Each line of resistance ribbon – line 1 to line 21 – refers to a specific alloy and sectional size combination. The cross-sectional sizes have been selected in order to have a globally coherent set of ohmic values for each alloy as well as a level of standardization between the different alloys groups: several lines of resistance ribbon with different types of alloys have the same ohmic value per turn and the same continuous rated current.

This is shown in table 1 where the ohmic values by turn $R_{turn}$ are given for each line by type of alloy : some lines using different types of alloy have the same ohmic value per turn and the same rated current. The performances of these lines differ, of course, in terms of:

- temperature coefficient of resistance, this coefficient depends on the alloy
- level of energy which can be absorbed during an instantaneous discharge: this value depends on the volumetric mass and the specific heat of the alloy as well as on the cross-sectional size of the resistance ribbon.

| Alloy A | Alloy B | Alloy C | Alloy D | $R_{turn}$ (mΩ) | $I_{perm}$ (A) |
|---|---|---|---|---|---|
| Line 1 | | | | 2.0 | 103 |
| Line 2 | | | | 2.5 | 93 |
| Line 3 | | | | 3.1 | 84 |
| | Line 4 | | | 4.5 | 78 |
| | Line 5 | | | 6.3 | 59 |
| | Line 6 | | Line 15 | 8.5 | 52 |
| | Line 7 | Line 9 | Line 16 | 12.6 | 42 |
| | Line 8 | Line 10 | Line 17 | 16.3 | 36 |
| | | Line 11 | Line 18 | 22 | 32 |
| | | Line 12 | Line 19 | 24 | 29 |
| | | Line 13 | Line 20 | 38 | 24 |
| | | Line 14 | Line 21 | 49 | 21 |

***Table 1:*** *(approximate) Ohmic values by turn and continuous rated currents for each line TOFIL or BC*

### Number of turns

The approximate ohmic value per turn given in table 1 can be used to select a standard model in the TOFIL or BC series according to table 2 or to check the feasibility, the number of turns must be between:

- **9 to 84 turns for TOFIL** resistors
- **9 to 105 turns for BC** resistors

These limits may vary depending on the required insulation voltage (standard dielectric voltage : 1,500 V).

| | TOFIL-1 | TOFIL-2 | TOFIL-3 | TOFIL-4 | TOFIL-5 | TOFIL-6 | TOFIL-7 | | |
|---|---|---|---|---|---|---|---|---|---|
| | BC-1 | BC-2 | BC-3 | BC-4 | BC-5 | BC-6 | BC-7 | BC-8 | BC-9 |
| **Number of turns** | 9 | 20 | 33 | 45 | 55 | 68 | 80 | 93 | 105 |

***Table 2:*** *Number of turns for the TOFIL and BC standard models*

## 3.2.2 Ohmic values

### Standard ohmic values

| Number of lines per type of alloy | | | | Ohmic values for the standard models (Ω) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | TOFIL-1 | TOFIL-2 | TOFIL-3 | TOFIL-4 | TOFIL-5 | TOFIL-6 | TOFIL-7 | | |
| A | B | C | D | BC-1 | BC-2 | BC-3 | BC-4 | BC-5 | BC-6 | BC-7 | BC-8 | BC-9 |
| 1 | | | | 0.018 | 0.040 | 0.065 | 0.089 | 0.109 | 0.135 | 0.158 | 0.184 | 0.21 |
| 2 | | | | 0.022 | 0.050 | 0.082 | 0.112 | 0.136 | 0.169 | 0.198 | 0.23 | 0.26 |
| 3 | | | | 0.028 | 0.063 | 0.104 | 0.142 | 0.173 | 0.21 | 0.25 | 0.29 | 0.33 |
| | 4 | | | 0.041 | 0.091 | 0.150 | 0.20 | 0.25 | 0.31 | 0.36 | 0.42 | 0.48 |
| | 5 | | | 0.057 | 0.127 | 0.21 | 0.29 | 0.35 | 0.43 | 0.51 | 0.59 | 0.67 |
| | 6 | | 15 | 0.077 | 0.170 | 0.28 | 0.38 | 0.47 | 0.58 | 0.68 | 0.79 | 0.89 |
| | 7 | 9 | 16 | 0.113 | 0.25 | 0.42 | 0.57 | 0.69 | 0.86 | 1.01 | 1.17 | 1.32 |
| | 8 | 10 | 17 | 0.147 | 0.33 | 0.54 | 0.74 | 0.90 | 1.11 | 1.31 | 1.52 | 1.72 |
| | | 11 | 18 | 0.196 | 0.44 | 0.72 | 0.98 | 1.20 | 1.48 | 1.74 | 2.02 | 2.28 |
| | | 12 | 19 | 0.22 | 0.49 | 0.80 | 1.10 | 1.34 | 1.66 | 1.95 | 2.26 | 2.56 |
| | | 13 | 20 | 0.32 | 0.71 | 1.17 | 1.60 | 1.96 | 2.42 | 2.85 | 3.31 | 3.73 |
| | | 14 | 21 | 0.44 | 0.97 | 1.61 | 2.19 | 2.68 | 3.31 | 3.90 | 4.53 | 5.12 |

***Table 3****: Standard ohmic values for TOFIL and BC series*

### Possible ohmic values

Every ohmic value may be supplied in the range of values given for each line of the TOFIL and BC series. The curves in diagrams 1 and 2 show the ohmic values for a given number of turns for the different lines of resistance ribbon, while also pointing out the continuous current for each.

Diagram 1 is for ohmic values above 1 ohm and diagram 2 is for lower values.

The limits corresponding to the BC series and to the TOFIL series are given at the top of each diagram. The standard values are indicated by dotted lines, above which the number of each standard model is given.

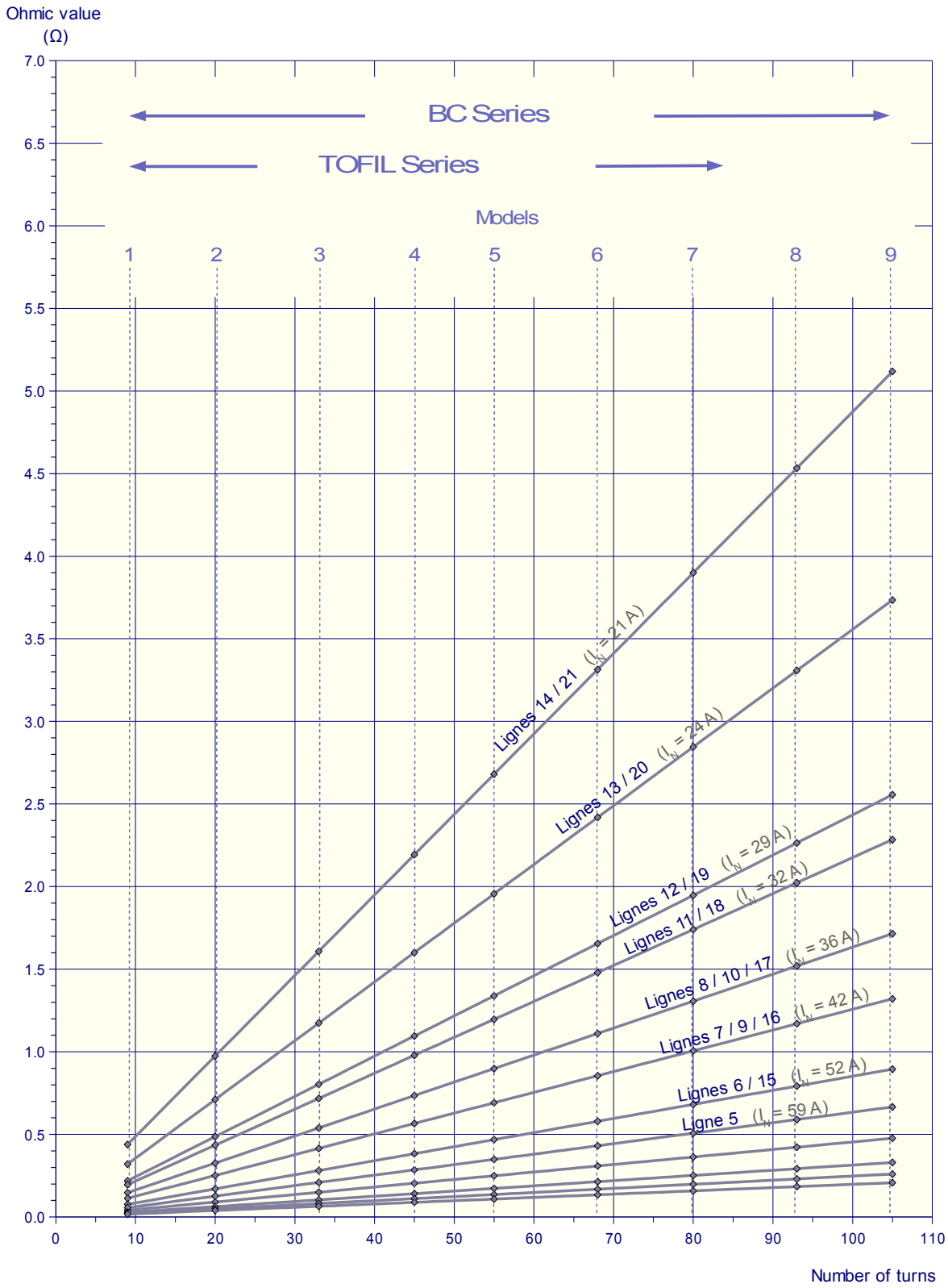



***Diagram 1:*** *Ohmic values (high values) vs. number of turns*

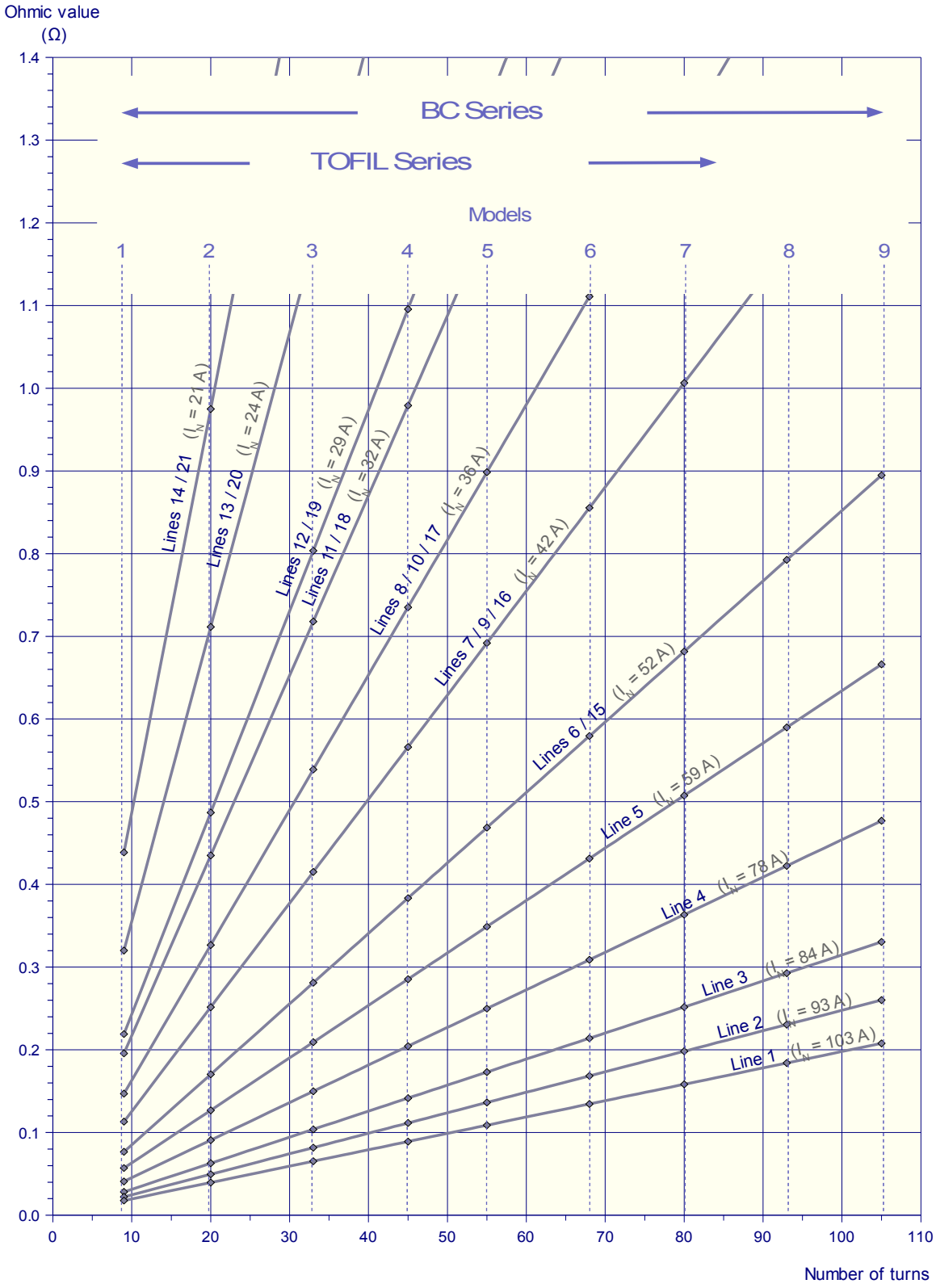



***Diagram 2:*** *Ohmic values (low values) vs. number of turns*

### 3.2.3 Continuous duty

- **Rated current**

  Rated current values are given in table 1 and diagrams 1 and 2. These values are for an ambient temperature of 25°C and for a temperature rise in the resistance coil of 375°C. For lines 4 to 21, the temperature rise in continuous duty can reach 450°C under specific conditions.

  The rated power can be significantly increased by forced-air cooling. Please contact us.

- **Rated current derating**

  When the ambient temperature is above 25°C, the rated current is reduced by a coefficient along the curve in diagram 3:

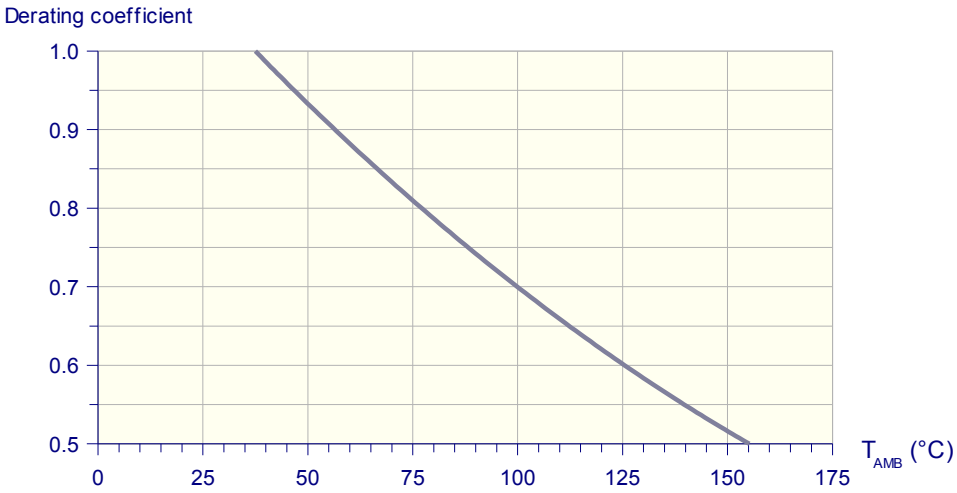



***Diagram 3:*** *Rated current derating curve*

- **Variation of the temperature of the coil**

  The temperature rise in the resistance coil depends on the current level. The curves in diagram 4 give the value of the temperature range vs. the current level for the different lines:

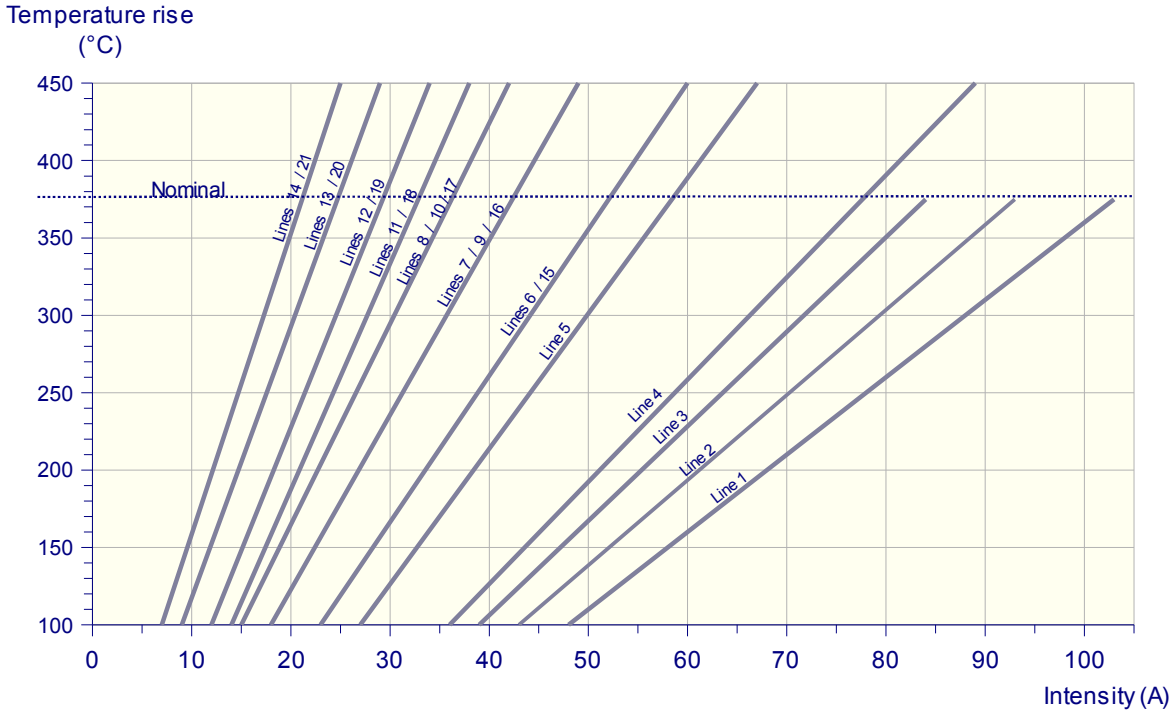



***Diagram 4:*** *Temperature rise of the resistance coil vs continuous current*

### 3.2.4 Instantaneous discharge

This occurs when there is a quick discharge through the resistor – theoretically instantaneous, practically a few tenths of a second – which is not repeated, at least until the resistance coil is back to its initial temperature. These conditions, with the acceptable overload levels of the resistance coils (400°C for the lines 1 to 3 and 600°C for the other lines), make it possible for the resistor to absorb an energy of a value E given in table 4 for the standard models of the TOFIL and BC series:

| (kilojoules) | TOFIL-1 | TOFIL-2 | TOFIL-3 | TOFIL-4 | TOFIL-5 | TOFIL-6 | TOFIL-7 | | |
|---|---|---|---|---|---|---|---|---|---|
| | BC-1 | BC-2 | BC-3 | BC-4 | BC-5 | BC-6 | BC-7 | BC-8 | BC-9 |
| **Line 1** | 46 | 102 | 168 | 229 | 279 | 346 | 406 | 473 | 534 |
| **Line 2** | 39 | 86 | 142 | 193 | 236 | 292 | 344 | 400 | 451 |
| **Line 3** | 29 | 64 | 106 | 145 | 177 | 219 | 257 | 299 | 338 |
| **Line 4** | 59 | 131 | 217 | 295 | 361 | 446 | 525 | 611 | 689 |
| **Line 5** | 37 | 82 | 135 | 184 | 225 | 278 | 327 | 380 | 429 |
| **Line 6** | 27 | 60 | 98 | 134 | 164 | 203 | 239 | 277 | 313 |
| **Line 7** | 19 | 41 | 68 | 93 | 113 | 140 | 165 | 192 | 216 |
| **Line 8** | 14 | 31 | 52 | 70 | 86 | 106 | 125 | 146 | 164 |
| **Line 9** | 27 | 60 | 100 | 136 | 166 | 205 | 241 | 281 | 317 |
| **Line 10** | 21 | 47 | 78 | 106 | 129 | 160 | 188 | 219 | 247 |
| **Line 11** | 16 | 35 | 57 | 78 | 96 | 118 | 139 | 162 | 183 |
| **Line 12** | 13 | 29 | 47 | 65 | 79 | 98 | 115 | 134 | 151 |
| **Line 13** | 9 | 21 | 34 | 47 | 57 | 71 | 83 | 97 | 109 |
| **Line 14** | 7 | 15 | 24 | 33 | 40 | 50 | 58 | 68 | 76 |
| **Line 15** | 44 | 98 | 161 | 220 | 269 | 332 | 391 | 454 | 513 |
| **Line 16** | 30 | 66 | 108 | 148 | 181 | 223 | 263 | 306 | 345 |
| **Line 17** | 23 | 51 | 85 | 115 | 141 | 174 | 205 | 238 | 269 |
| **Line 18** | 17 | 38 | 62 | 85 | 104 | 129 | 151 | 176 | 199 |
| **Line 19** | 14 | 31 | 52 | 71 | 86 | 107 | 125 | 146 | 165 |
| **Line 20** | 10 | 23 | 37 | 51 | 62 | 77 | 91 | 105 | 119 |
| **Line 21** | 7 | 16 | 26 | 36 | 44 | 54 | 64 | 74 | 83 |

***Table 4:*** *Acceptable instantaneous energy (in kilojoules) by model and line*

### 3.2.5 Short time duty

In this type of duty, the current flows through the resistor during a “current flow time” $T_A$, typically from one to several tens of seconds, then the resistor cools down during the rest time $T_R$, this value depends on the resistance coil and on the line number of the resistor. Table 5 gives the value of the rated current per line number for values of $T_A$ from one second to one minute, with the minimum rest-time value $T_R$ indicated for each line number:

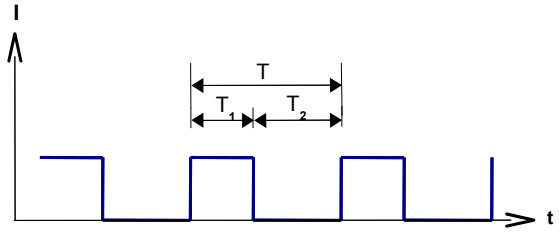
| (ampères) | Current flow time $T_A$ (s) | | | | | | | | | | | Minimum rest time $T_R$ (s) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 1,5 | 2 | 3 | 4 | 5 | 7 | 10 | 20 | 30 | 60 | |
| **Line 1** | 1650 | 1300 | 1100 | 850 | 720 | 625 | 520 | 420 | 280 | 235 | 175 | 1850 |
| **Line 2** | 1300 | 1050 | 870 | 680 | 570 | 500 | 420 | 335 | 230 | 185 | 150 | 1450 |
| **Line 3** | 1000 | 800 | 670 | 530 | 450 | 400 | 300 | 275 | 185 | 165 | 130 | 1200 |
| **Line 4** | 1200 | 930 | 680 | 600 | 510 | 450 | 370 | 300 | 200 | 170 | 130 | 2200 |
| **Line 5** | 800 | 620 | 520 | 400 | 340 | 300 | 250 | 200 | 145 | 125 | 97 | 1700 |
| **Line 6** | 600 | 455 | 380 | 300 | 260 | 230 | 185 | 160 | 120 | 96 | 80 | 1100 |
| **Line 7** | 400 | 325 | 275 | 220 | 190 | 170 | 140 | 120 | 82 | 70 | 60 | 800 |
| **Line 8** | 310 | 250 | 210 | 170 | 145 | 130 | 107 | 87 | 65 | 57 | 48 | 600 |
| **Line 9** | 500 | 400 | 340 | 275 | 240 | 215 | 180 | 151 | 112 | 90 | 67 | 1350 |
| **Line 10** | 375 | 310 | 265 | 215 | 185 | 165 | 140 | 120 | 85 | 70 | 53 | 1000 |
| **Line 11** | 285 | 230 | 195 | 165 | 145 | 130 | 110 | 91 | 65 | 55 | 43 | 750 |
| **Line 12** | 235 | 190 | 165 | 140 | 120 | 112 | 90 | 75 | 54 | 45 | 38 | 650 |
| **Line 13** | 165 | 138 | 120 | 94 | 80 | 72 | 62 | 52 | 39 | 34 | 29 | 600 |
| **Line 14** | 120 | 98 | 85 | 69 | 60 | 53 | 46 | 39 | 30 | 27 | 23 | 450 |
| **Line 15** | 750 | 600 | 510 | 410 | 350 | 310 | 267 | 215 | 155 | 130 | 84 | 1600 |
| **Line 16** | 510 | 415 | 350 | 280 | 240 | 215 | 180 | 150 | 110 | 90 | 69 | 1200 |
| **Line 17** | 400 | 320 | 270 | 215 | 180 | 165 | 140 | 120 | 83 | 70 | 55 | 950 |
| **Line 18** | 290 | 235 | 190 | 165 | 140 | 125 | 105 | 90 | 67 | 57 | 53 | 700 |
| **Line 19** | 250 | 200 | 175 | 140 | 125 | 110 | 90 | 77 | 58 | 51 | 42 | 600 |
| **Line 20** | 170 | 145 | 120 | 98 | 85 | 75 | 67 | 57 | 44 | 40 | 33 | 500 |
| **Line 21** | 120 | 98 | 85 | 69 | 60 | 54 | 47 | 43 | 33 | 30 | 26 | 450 |

***Table 5:*** *Acceptable current levels per line in short time duty*

### 3.2.6 Intermittent periodic duty

In this type of duty, the current flows across the resistor for a period of time $T_1$, then stops (I = 0) during the rest time $T_2$, and then a new cycle starts: the cycle time is $T = T_1 + T_2$.

At the end of the rest time, the resistance coil is at an intermediary temperature between the temperature which would be reached in continuous duty and the ambient temperature. Table 6 gives the acceptable currents for each line - except for those corresponding to the alloy B, which is not used in these applications due to its high TCR (Temperature Coefficient of Resistance) – for a set of values of the cycle time T and of the duty cycle $d = T_1/T$:




| Cycle time T (s) | 15 | 15 | 15 | 60 | 60 | 60 | 240 | 240 | 240 |
|---|---|---|---|---|---|---|---|---|---|
| $d = T_1/T$ | 15% | 30% | 50% | 15% | 30% | 50% | 15% | 30% | 50% |
| $T_1$ (s) | 2.3 | 5 | 7.5 | 9 | 18 | 30 | 36 | 72 | 120 |
| $T_2$ (s) | 12.7 | 10 | 7.5 | 51 | 42 | 30 | 204 | 168 | 120 |
| Line 1 | 290 | 190 | 145 | 270 | 190 | 146 | 230 | 170 | 140 |
| Line 2 | 260 | 160 | 140 | 220 | 174 | 134 | 182 | 142 | 118 |
| Line 3 | 230 | 145 | 115 | 220 | 154 | 120 | 160 | 124 | 106 |
| Line 15 | 145 | 90 | 70 | 130 | 96 | 72 | 108 | 80 | 66 |
| Lines 9 and 16 | 115 | 70 | 56 | 110 | 77 | 58 | 83 | 65 | 52 |
| Lines 10 and 17 | 97 | 62 | 48 | 92 | 82 | 47 | 70 | 56 | 45 |
| Lines 11 and 18 | 90 | 55 | 45 | 70 | 52 | 42 | 58 | 47 | 40 |
| Lines 12 and 19 | 82 | 52 | 41 | 78 | 55 | 42 | 55 | 43 | 37 |
| Lines 13 and 20 | 45 | 34 | 30 | 47 | 35 | 28 | 40 | 31 | 27 |
| Lines 14 and 21 | 52 | 33 | 26 | 38 | 28 | 23 | 33 | 27 | 22 |

***Table 6:*** *Acceptable current levels (in amps) per line in intermittent periodic duty*

### 3.2.7 Voltage insulation

#### Operating voltage

TOFIL and BC resistors are designed to operate under voltages up to 440 $V_{AC}$ or 350 $V_{DC}$.

#### Insulation voltage

The insulation voltage (between the resistance coil and mounting brackets) of each TOFIL or BC resistor is checked in production under a voltage of 1,500 $V_{AC}$ /50 Hz.

When a higher insulation voltage is required :

- the dimension of the TOFIL resistors is adjusted to increase the distance between the coil and the brackets.
- an optional "secondary insulation" feature allows tan increase in the insulation voltage of the BC-3 to BC-9 resistors above 5,000 V (depending on the complete mounting structure). See description on page 19.

#### Insulation resistance

The insulation resistance (between the resistance coil and mounting brackets) is higher than 100 MΩ under a DC voltage of 500 V . This point is checked in production on each unit.

### 3.2.8 Inductance

The inductance value of the TOFIL or BC resistor vs. the number of turns is given by the curve in diagram 5. The curve shows only an approximate value, other parameters must be taken into account, such as the presence of a treading rod (TOFIL) or of intermediary lugs. If this value is important for the application, special precautions can be taken to limit its value. Please contact us.

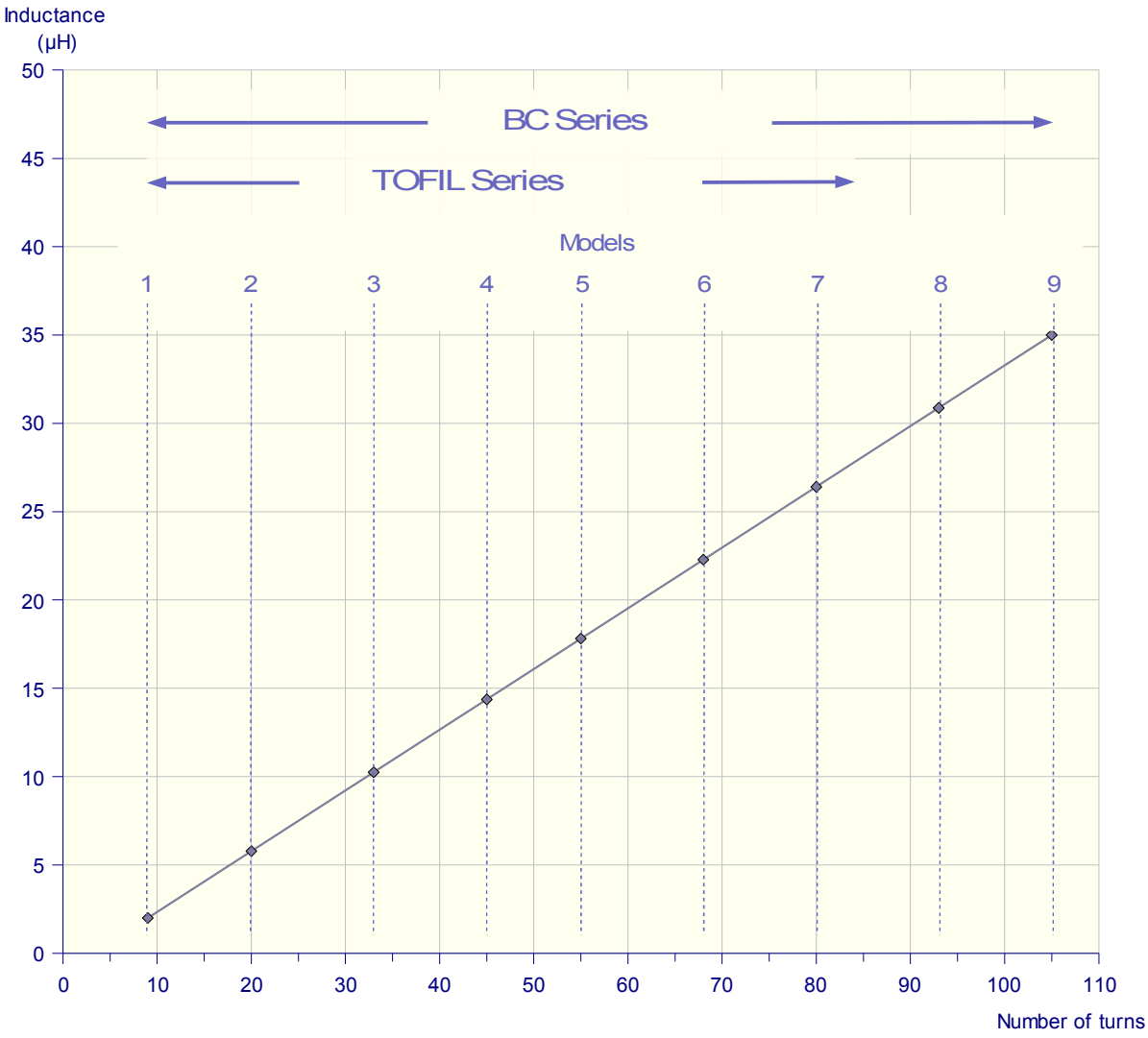
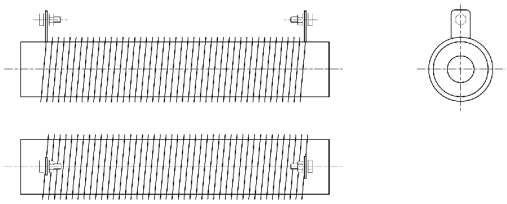
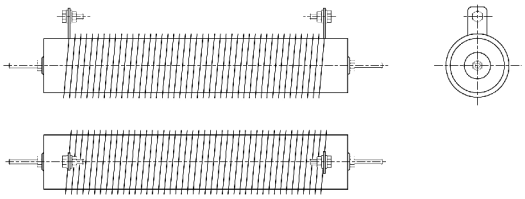
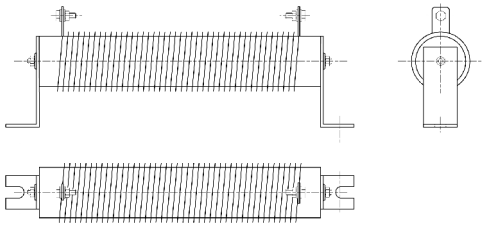
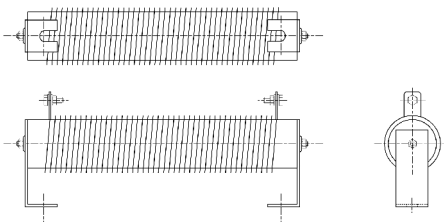
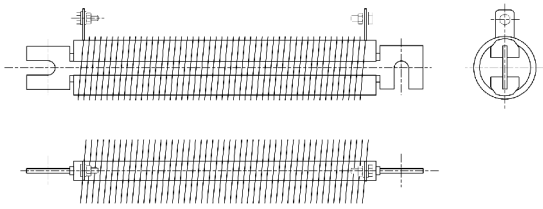
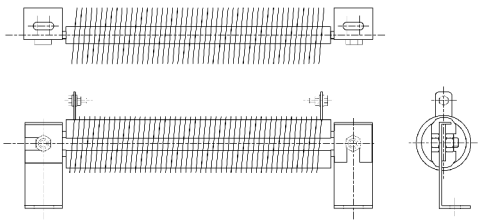
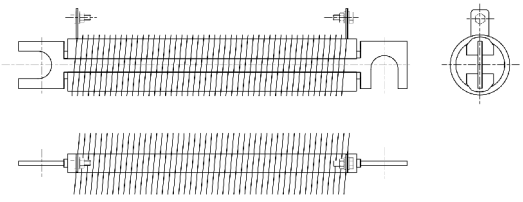
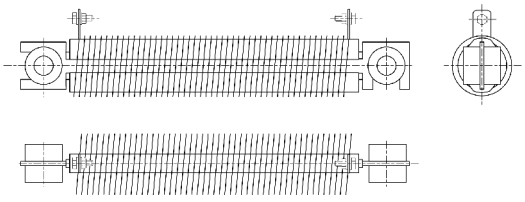



Diagram 5: Inductance value for TOFIL and BC resistors

## 3.3 Mechanical Specifications

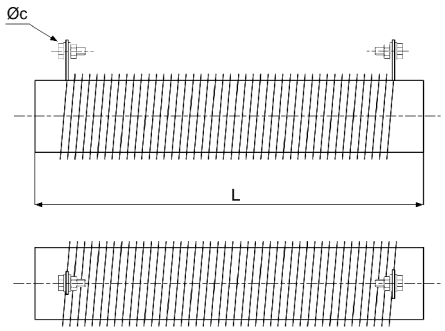
### 3.3.1 Mounting styles overview table

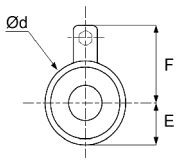
| | | |
|---|---|---|
| TOFIL |  **Unmounted** |  **With threaded rod** |
| |  **PS mounting brackets** |  **ID mounting brackets** |
| BC |  **Unmounted** |  **PS mounting brackets** |
| |  **For secondary insulation (without insulators)** |  **With secondary isolation (with insulators)** |

## 3.3.2 Dimensions

**TOFIL**:

- Unmounted resistor



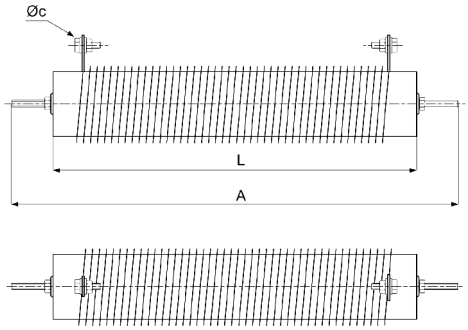



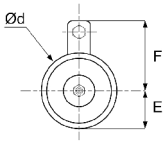

*Example: Model TOFIL6BXX0R59*

| (mm) | TOFIL-1 | TOFIL-2 | TOFIL-3 | TOFIL-4 | TOFIL-5 | TOFIL-6 | TOFIL-7 |
|---|---|---|---|---|---|---|---|
| **L** | 90 | 156 | 236 | 306 | 366 | 444 | 516 |
| **Øc** | 8.5 | 8.5 | 8.5 | 8.5 | 8.5 | 8.5 | 8.5 |
| **Ød**[1] | 56 | 56 | 56 | 56 | 56 | 56 | 56 |
| **E** | 28 | 28 | 28 | 28 | 28 | 28 | 28 |
| **F** | 56 | 56 | 56 | 56 | 56 | 56 | 56 |

*1: Values are average values and depend on the type (= on the line) of the resistance ribbon used*

- With threaded rod



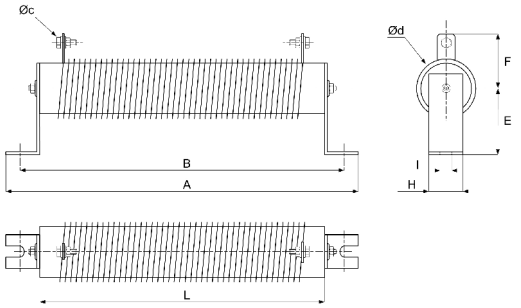




*Example: Model TOFIL6BXT0R59*

| (mm) | TOFIL-1 | TOFIL-2 | TOFIL-3 | TOFIL-4 | TOFIL-5 | TOFIL-6 | TOFIL-7 |
|---|---|---|---|---|---|---|---|
| **A** | 170 | 236 | 314 | 386 | 446 | 524 | 596 |
| **Øc** | 8.5 | 8.5 | 8.5 | 8.5 | 8.5 | 8.5 | 8.5 |
| **Ød**[1] | 56 | 56 | 56 | 56 | 56 | 56 | 56 |
| **E** | 28 | 28 | 28 | 28 | 28 | 28 | 28 |
| **L** | 90 | 156 | 234 | 306 | 366 | 444 | 516 |
| **F** | 56 | 56 | 56 | 56 | 56 | 56 | 56 |

*1: Values are average values and depend on the type (= on the line) of the resistance ribbon used*

- PS mounting brackets

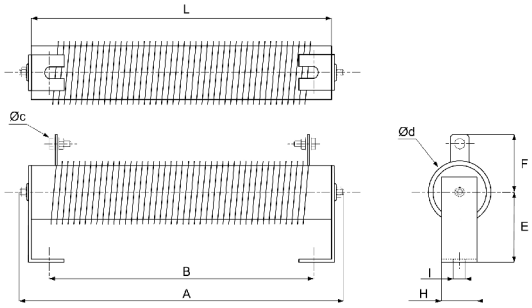



*Example: Model TOFIL4CXPSX0R9*

| (mm) | TOFIL-1 | TOFIL-2 | TOFIL-3 | TOFIL-4 | TOFIL-5 | TOFIL-6 | TOFIL-7 |
|---|---|---|---|---|---|---|---|
| **A** | 132 | 198 | 276 | 328 | 408 | 486 | 558 |
| **B** | 117 | 183 | 261 | 333 | 393 | 471 | 543 |
| **Øc** | 8.5 | 8.5 | 8.5 | 8.5 | 8.5 | 8.5 | 8.5 |
| **Ød[1]** | 56 | 56 | 56 | 56 | 56 | 56 | 56 |
| **E** | 45 | 45 | 45 | 45 | 45 | 45 | 45 |
| **L** | 90 | 156 | 234 | 306 | 366 | 444 | 516 |
| **F** | 56 | 56 | 56 | 56 | 56 | 56 | 56 |
| **I** | 9 | 9 | 9 | 9 | 9 | 9 | 9 |
| **H** | 30 | 30 | 30 | 30 | 30 | 30 | 30 |

*1 : Values are average values and depend on the type (= on the line) of the resistance ribbon used*

- ID mounting brackets



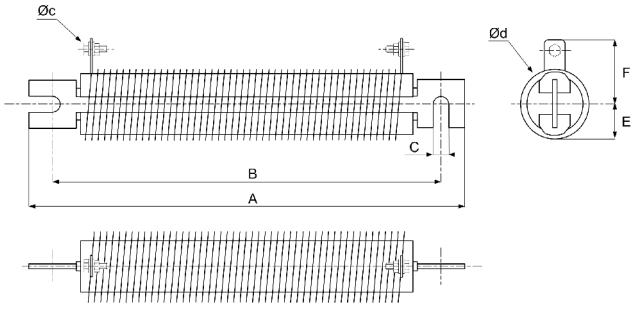

*Example: Model TOFIL6BXID0R59*

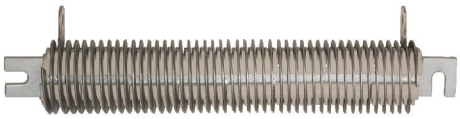
| (mm) | TOFIL-1 | TOFIL-2 | TOFIL-3 | TOFIL-4 | TOFIL-5 | TOFIL-6 | TOFIL-7 |
|---|---|---|---|---|---|---|---|
| **A** | 90 | 156 | 236 | 306 | 366 | 444 | 516 |
| **B** | 116 | 182 | 260 | 332 | 392 | 470 | 542 |
| **Øc** | 8.5 | 8.5 | 8.5 | 8.5 | 8.5 | 8.5 | 8.5 |
| **Ød[1]** | 56 | 56 | 56 | 56 | 56 | 56 | 56 |
| **E** | 45 | 45 | 45 | 45 | 45 | 45 | 45 |
| **L** | 90 | 156 | 234 | 306 | 366 | 444 | 516 |
| **F** | 56 | 56 | 56 | 56 | 56 | 56 | 56 |
| **I** | 9 | 9 | 9 | 9 | 9 | 9 | 9 |
| **H** | 30 | 30 | 30 | 30 | 30 | 30 | 30 |

*1 : Values are average values and depend on the type (= on the line) of the resistance ribbon used*

## BC Resistors

- Unmounted resistor



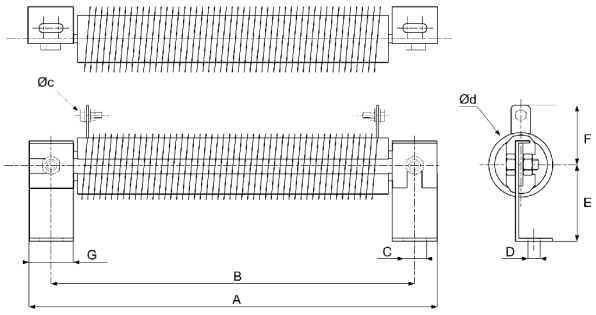



*Example: Model BC4CXXSS1R5*

| (mm) | BC-1 | BC-2 | BC-3 | BC-4 | BC-5 | BC-6 | BC-7 | BC-8 | BC-9 |
|---|---|---|---|---|---|---|---|---|---|
| **A** | 118 | 191 | 266 | 338 | 413 | 486 | 561 | 631 | 709 |
| **B** | 94 | 167 | 244 | 314 | 389 | 462 | 537 | 607 | 685 |
| **C** | 10.2 | 10.2 | 10.2 | 10.2 | 10.2 | 10.2 | 10,2 | 10.2 | 10.2 |
| **Øc** | 8.5 | 8.5 | 8.5 | 8.5 | 8.5 | 8.5 | 8.5 | 8.5 | 8.5 |
| **E** | 28 | 28 | 28 | 28 | 28 | 28 | 28 | 28 | 28 |
| **F** | 56 | 56 | 56 | 56 | 56 | 56 | 56 | 56 | 56 |
| **Ød[1]** | 56 | 56 | 56 | 56 | 56 | 56 | 56 | 56 | 56 |

*1: Values are average values and depend on the type (= on the line) of the resistance ribbon used*

- PS mounting brackets



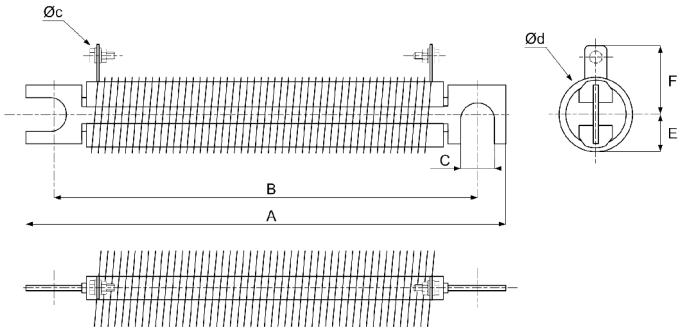

*Example : Model BC4CXPSS1R5*

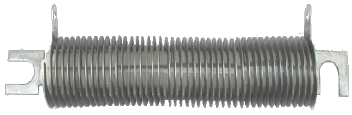
| (mm) | BC-1 | BC-2 | BC-3 | BC-4 | BC-5 | BC-6 | BC-7 | BC-8 | BC-9 |
|---|---|---|---|---|---|---|---|---|---|
| **A** | 118 | 191 | 266 | 338 | 413 | 486 | 561 | 631 | 709 |
| **B** | 94 | 167 | 244 | 314 | 389 | 462 | 537 | 607 | 685 |
| **C** | 14 | 14 | 14 | 14 | 14 | 14 | 14 | 14 | 14 |
| **D** | 8.5 | 8.5 | 8.5 | 8.5 | 8.5 | 8.5 | 8.5 | 8.5 | 8.5 |
| **E** | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 |
| **F** | 56 | 56 | 56 | 56 | 56 | 56 | 56 | 56 | 56 |
| **Øc** | 8.5 | 8.5 | 8.5 | 8.5 | 8.5 | 8.5 | 8.5 | 8.5 | 8.5 |
| **Ød[1]** | 56 | 56 | 56 | 56 | 56 | 56 | 56 | 56 | 56 |
| **G** | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 |

*1: Values are average values and depend on the type (= on the line) of the resistance ribbon used*

- BC resistor for “secondary insulation”

  BC resistors for “secondary insulation” have a slotted mounting bar which can be mounted with secondary ceramic insulators. The insulators are not supplied with the resistors in this configuration.



*Example: Model BC4CXXSS1R5*

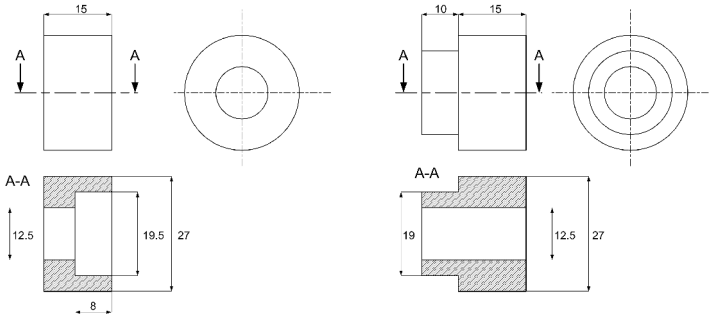
| (mm) | BC-1 | BC-2 | BC-3 | BC-4 | BC-5 | BC-6 | BC-7 | BC-8 | BC-9 |
|---|---|---|---|---|---|---|---|---|---|
| **A** | 128 | 201 | 276 | 349 | 423 | 496 | 571 | 641 | 719 |
| **B** | 95 | 168 | 242 | 315 | 390 | 463 | 538 | 611 | 685 |
| **C** | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 |
| **Øc** | 8.5 | 8.5 | 8.5 | 8.5 | 8.5 | 8.5 | 8.5 | 8.5 | 8.5 |
| **E** | 28 | 28 | 28 | 28 | 28 | 28 | 28 | 28 | 28 |
| **F** | 56 | 56 | 56 | 56 | 56 | 56 | 56 | 56 | 56 |
| **Ød**[1] | 56 | 56 | 56 | 56 | 56 | 56 | 56 | 56 | 56 |

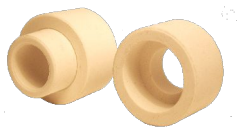
*1: Values are average values and depend on the type (= on the line) of the resistance ribbon used*

- BC resistor with “secondary insulation” (option)

  The resistors here the same as above but are supplied with the insulators: 2 two-piece insulators - not mounted on the resistors – provide secondary insulation at both ends of the resistor.

  Dimensions of the insulators :



*Two-piece insulator*

Example of a BC resistor with “secondary insulation” :

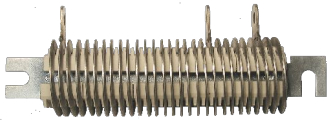
### 3.3.3 Terminals

Connections to the BC and TOFIL resistors are made by nuts and screws on the ends and optionally on intermediary terminals.
**Screws for each terminal are supplied with the resistors** (included : screw, nut, washer and lock-washer, plus a specific part called a "fork" for the BC resistors).

- **Welded terminal** at both ends of the resistor and optionally as intermediary lugs

The resistors can be fitted with one or more welded intermediary lugs. Their size is the same as the size of the terminals at the ends of the resistor, described in the drawings on the previous pages.

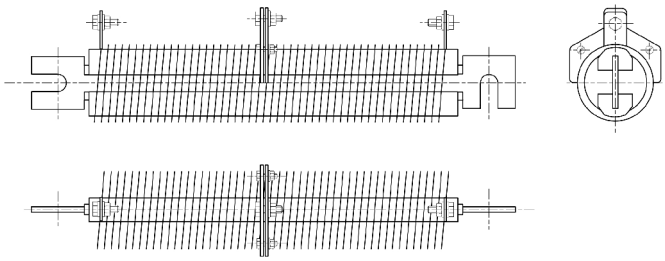
*TOFIL resistor with welded intermediary lug*



*BC resistor with welded intermediary lug*

- **Adjustable terminal**

The resistors can be fitted with one or more optional adjustable terminals :



*Example of adjustable terminal on a BC resistor*

## 3.3.4 Weights

- **Weights of TOFIL resistors** (approximate values in grams, brackets excluded)

| Line N° | TOFIL-1 | TOFIL-2 | TOFIL-3 | TOFIL-4 | TOFIL-5 | TOFIL-6 | TOFIL-7 |
|---|---|---|---|---|---|---|---|
| 1 | 465 | 840 | 1200 | 1670 | 2055 | 2480 | 2915 |
| 2 | 405 | 715 | 1060 | 1400 | 1715 | 2065 | 2425 |
| 3 | 370 | 635 | 940 | 1235 | 1505 | 1760 | 2175 |
| 4 | 505 | 925 | 1400 | 1785 | 2285 | 2790 | 3225 |
| 5 | 405 | 715 | 1070 | 1405 | 1715 | 2070 | 2425 |
| 6 | 370 | 650 | 965 | 1260 | 1540 | 1865 | 2170 |
| 7 | 320 | 540 | 795 | 1040 | 1260 | 1505 | 1760 |
| 8 | 300 | 500 | 725 | 950 | 1140 | 1375 | 1600 |
| 9 and 16 | 390 | 670 | 1025 | 1340 | 1645 | 1990 | 2315 |
| 10 and 17 | 355 | 600 | 905 | 1130 | 1445 | 1735 | 2020 |
| 11 and 18 | 318 | 530 | 795 | 1035 | 1255 | 1505 | 1760 |
| 12 and 19 | 310 | 500 | 755 | 980 | 1190 | 1430 | 1670 |
| 13 and 20 | 280 | 450 | 665 | 860 | 1030 | 1635 | 1460 |
| 14 and 21 | 270 | 430 | 625 | 810 | 975 | 1160 | 1350 |
| 15 | 445 | 775 | 1200 | 1585 | 1945 | 2340 | 2725 |

- **Weights of BC resistors** (approximate values in grams, brackets and insulators excluded)

| Line N° | BC-1 | BC-2 | BC-3 | BC-4 | BC-5 | BC-6 | BC-7 | BC-8 | BC-9 |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 430 | 805 | 1140 | 1645 | 2075 | 2495 | 2925 | 3300 | 3790 |
| 2 | 370 | 680 | 1000 | 1375 | 1735 | 2080 | 2435 | 2720 | 3150 |
| 3 | 335 | 600 | 880 | 1210 | 1525 | 1775 | 2185 | 2440 | 2730 |
| 4 | 470 | 890 | 1340 | 1720 | 2235 | 2710 | 3130 | 3550 | 4090 |
| 5 | 370 | 680 | 1010 | 1340 | 1665 | 1990 | 2330 | 2650 | 3030 |
| 6 | 335 | 615 | 910 | 1195 | 1490 | 1785 | 2075 | 2345 | 2680 |
| 7 | 285 | 505 | 736 | 975 | 1210 | 1424 | 1665 | 1885 | 2165 |
| 8 | 265 | 465 | 665 | 885 | 1090 | 1295 | 1505 | 1695 | 1945 |
| 9 and 16 | 355 | 635 | 965 | 1275 | 1595 | 1910 | 2220 | 2500 | 2870 |
| 10 and 17 | 320 | 565 | 845 | 1065 | 1395 | 1655 | 1925 | 2195 | 2515 |
| 11 and 18 | 285 | 495 | 735 | 970 | 1205 | 1425 | 1665 | 1880 | 2165 |
| 12 and 19 | 275 | 465 | 700 | 915 | 1140 | 1350 | 1575 | 1775 | 2035 |
| 13 and 20 | 245 | 415 | 605 | 795 | 980 | 1155 | 1365 | 1515 | 1735 |
| 14 and 21 | 235 | 395 | 565 | 745 | 925 | 1080 | 1255 | 1415 | 1615 |
| 15 | 410 | 740 | 1140 | 1560 | 1965 | 2355 | 2735 | 3120 | 3980 |

## 3.4 Product Identification Code

| TOFIL7 | D | X | PS | X | 2R85 |
|---|---|---|---|---|---|

**Model:**

TOFIL1 to TOFIL7
BC1 to BC9

**Total ohmic value:**

nnnRddd for nnn.ddd Ω
Ex. : 2R85 for 2.85 ohms

**Type of alloy:**

"A": silver-nickel
"B": stainless steel
"C": chrome-aluminum
"D": nickel-chrome

**Insulation:**

"X": TOFIL
"S": unmounted BC (standard)
"D": BC for secondary insulation (without insulator)
"C": BC with secondary insulation (with insulators)

**Intermediary terminal :**

"X": without
"F": welded terminal
"A": adjustable terminal

**Mounting style:**

"X": unmounted
"PS": PS brackets
"ID": TOFIL with ID mounting brackets
"T": TOFIL with threaded rod

This identification code above is followed:
– when ordering, from the list of the optional features which are not described in the code,
– Internally from a special code if the product cannot be considered as a standard model.

# 4 Other Series and Models

## 4.1 "ZOFIL" Series

The ZOFIL series is designed for "traction" (railway) applications.

*Example of ZOFIL series resistor*

- **Description** : The resistors in the ZOFIL series are constructed with:
  - a resistance coil (the same as in the TOFIL and BC series), in chromium-nickel alloy,
  - a one-piece grooved ceramic tube, designed to withstand a rapid temperature rise of 800°C,
  - brackets-terminals welded to the resistance coil.
- **Characteristics**: In this series, there are 3 models/sizes with 14 possible ohmic values for each, which use the same resistance ribbon in alloy D (nickel-chromium) as the TOFIL and BC of lines 15 to 21 (other values possible on request).
  The instantaneous energy and the rated currents for temperature rises of 300°C, 350°C and 400°C are given by model and line number (/ohmic values) in the following table (maximum working temperature: 600°C, including ambient temperature).

  Please contact us for more information.

| Line number | | 15 | 16 | 17 | 18 | 19 | 20 | 21 |
|---|---|---|---|---|---|---|---|---|
| **Model ZOFIL-4** | **Ohmic value (Ω)** | **0.38** | **0.57** | **0.735** | **1.00** | **1.10** | **1.65** | **2.2** |
| | Energy (kJ) | 217 | 146 | 123 | 84 | 69 | 49 | 36 |
| **Model ZOFIL-5** | **Ohmic value (Ω)** | **0.49** | **0.72** | **0.93** | **1.24** | **1.38** | **2.08** | **2.78** |
| | Energy (kJ) | 275 | 185 | 143 | 107 | 89 | 60 | 45 |
| **Model ZOFIL-6** | **Ohmic value (Ω)** | **0.59** | **0.87** | **1.13** | **1.50** | **1.68** | **2.52** | **3.36** |
| | Energy (kJ) | 337 | 227 | 173 | 130 | 108 | 75 | 55 |
| Current (Amps) for a temperature rise of 300°C | | 44 | 36 | 31 | 27 | 24 | 20 | 18 |
| Current (Amps) for a temperature rise of 375°C | | 52 | 42 | 36 | 32 | 29 | 24 | 21 |
| Current (Amps) for a temperature rise of 450°C | | 60 | 49 | 42 | 38 | 34 | 28 | 25 |

Main characteristics for ZOFIL-4 to ZOFIL-6

## 4.2 M17 Series

M17 resistors are similar to BC resistors, but the mounting bar and ceramic insulators are different, requiring a different mounting mode and a different step in the resistance coil.

They are supplied to replace old parts, based on the designation of the resistor to be replaced.

# 5 Edgewound Resistor Assemblies

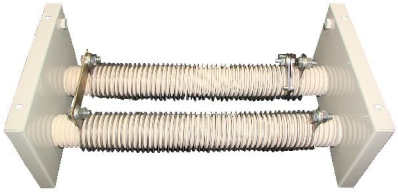
Resistor assemblies can be supplied as open frames, available to OEM's for mounting in their own enclosure. or in indoor/outdoor enclosures.

## 5.1 Open Frame Constructions

Zinc-plated steel brackets are used as the standard. Aluminum, stainless steel or painted steel may be used on request. Terminal connections may be made as in the resistor terminals or may be done by connecting plugs or blocks.

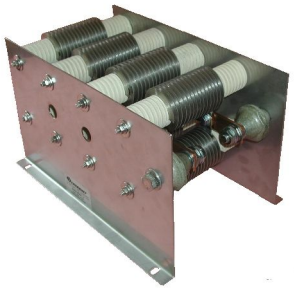
Examples of open frame assemblies using edgewound resistors:

*E1507*
*(railway application)*



*E1510*
*(painted steel brackets)*

*E1391*
*(BC resistors)*



*E1360*
*(TOFIL resistors)*

*E1007*
*(railway application)*

*E1462*
*(BC resistors)*

*E1463*
*(BC resistors)*

*E1395*
*(operating voltage: 11 kV)*

## 5.2 Resistor Enclosures

Resistors or resistor assemblies can be packaged in metallic boxes/enclosures/cages to meet a required protection level, usually IP20 to IP23.

Enclosures are made of white zinc plated steel, or optionally of painted steel, aluminum or stainless steel.

Terminal connections can be done using connecting sockets, connecting blocks on the front, side or rear panels, a screw-fastened door for user protection, etc.

Other accessories may be added, such as switches. When the ohmic value can be selected by switches, the resistor box is considered as a bench or a load bank, described in a separate document.

Examples of edgewound resistor assemblies in cages/boxes/enclosures:

*E1461*
*(IP 20)*

*E1548*
*(IP 20)*

*E1551*
*(IP 20)*

*E1540*
*(mobile /with fans)*

*E1394*
*(IP 23)*

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