

電線の許容電流

Allowable current for electric wires

許容電流計算式

1. 絶縁電線の許容電流は次式により計算します。(JCS 168 号 C)
(空中又は暗渠に布設される単心ケーブル)

$$I = \eta_0 \sqrt{\frac{T_1 - T_2}{r \cdot R_{th}}}$$

$$= \eta_0 \sqrt{\frac{T_1 - 40}{r \cdot R_{th}}} \quad (\text{基底温度 } 40^\circ\text{C の場合})$$

(For the base temperature of 40°C)

$$r = \{1 + \alpha (T_1 - 20)\} r_0$$

$$= \{1 + 0.00393 (T_1 - 20)\} r_0 \quad (\text{銅導体の場合})$$

(For copper conductor)

$$R_{th} = R_1 + R_3$$

$$R_1 = \frac{\rho_1}{2\pi} \ln \frac{d_2}{d_1}$$

$$R_3 = \frac{10\rho_3}{\pi d_2}$$

ρ_1 : 絶縁体の固有熱抵抗 [$^\circ\text{C} \cdot \text{cm}/\text{W}$] ρ_1 : Specific thermal resistance of insulation [$^\circ\text{C} \cdot \text{cm}/\text{W}$]	
ポリエチレン Polyethylene	450
架橋ポリエチレン Crosslinked polyethylene	450
PVC	600
架橋PVC Crosslinked PVC	600
硅素ゴム Silicon rubber	500
エチレンプロピレンゴム Ethylene propylene rubber	500
ブチルゴム Butyl rubber	500
クロロプレンゴム Chloroprene rubber	500
ハイパロンゴム Hypalon rubber	500
FEP	400

ρ_3 : 表面放散熱抵抗 [$^\circ\text{C} \cdot \text{cm}^2/\text{W}$] ρ_3 : Surface thermal radiation resistance [$^\circ\text{C} \cdot \text{cm}^2/\text{W}$]	
上表の物 Materials shown in the upper table	$500 + 10d_2$ ($d_2 \leq 40$)
含浸編組 Impregnated braid	$400 + 20d_2$ ($d_2 \leq 20$)
〃	800 ($d_2 > 20$)

Allowable current calculation formula

1. The allowable current of an insulated wire is calculated as follows. (JCS 168 C)
(Single core cable laid in air or duct)

I	: 許容電流 [A] : Allowable current [A]
T_1	: 導体最高許容温度 [$^\circ\text{C}$] (絶縁体耐熱温度) : Maximum allowable conductor temperature [$^\circ\text{C}$] (Allowable insulation temperature)
T_2	: 周囲温度 (一般に 40°C) : Ambient temperature (generally 40°C)
r	: 電線の T_1 $^\circ\text{C}$ における導体実効抵抗 [Ω/cm] : Effective conductor resistance at T_1 $^\circ\text{C}$ [Ω/cm]
r_0	: 電線の 20°C における導体実効抵抗 [Ω/cm] : Effective conductor resistance at 20°C [Ω/cm]
α	: 導体抵抗の温度係数 銅線の場合 0.00393 アルミの場合 0.0040 : Temperature coefficient of conductor resistance For copper wire: 0.00393 For aluminum wire: 0.0040
R_{th}	: 全熱抵抗 [$^\circ\text{C} \cdot \text{cm}/\text{W}$] : Total thermal resistance [$^\circ\text{C} \cdot \text{cm}/\text{W}$]
R_1	: 絶縁体の熱抵抗 [$^\circ\text{C} \cdot \text{cm}/\text{W}$] : Thermal resistance of insulation [$^\circ\text{C} \cdot \text{cm}/\text{W}$]
R_3	: 電線表面放散熱抵抗 [$^\circ\text{C} \cdot \text{cm}/\text{W}$] : Radiation thermal resistance at wire surface [$^\circ\text{C} \cdot \text{cm}/\text{W}$]
d_1	: 導体外径 [mm] : Conductor outside dia. [mm]
d_2	: 絶縁体外径 [mm] : Insulation outside dia. [mm]
η_0	: 多数布設する場合の許容電流低減率 : Reduction ratio of allowable current for multiple wire laying
ρ_1	: 絶縁体の固有熱抵抗 [$^\circ\text{C} \cdot \text{cm}/\text{W}$] : Specific thermal resistance of insulation [$^\circ\text{C} \cdot \text{cm}/\text{W}$]
ρ_3	: 表面放散熱抵抗 [$^\circ\text{C} \cdot \text{cm}^2/\text{W}$] : Surface thermal radiation resistance [$^\circ\text{C} \cdot \text{cm}^2/\text{W}$]

最高許容温度 ($^\circ\text{C}$) (各材料の耐熱性参照) Max. allowable temperatur ($^\circ\text{C}$) (refer to the heat resistance of each material)	
一般PVC General PVC	60
耐熱PVC Heat resistant PVC	45, 80, 90, 105
ポリエチレン Polyethylene	75
架橋ポリエチレン Crosslinked polyethylene	90
ブチルゴム Butyl rubber	80
FEP	200
ビーメックス BEAMEX	(耐熱性参照) Refer to the heat resistance specification (一般使用) For general use
	VF, VC 105
	NF 125
	ER470 125
	ER500 150

2. 絶縁電線を隣接して多数布設する場合は、低減率を掛けなければならない。

2. Reduction ratio shall be multiplied when multiple insulated wires are laid side-by-side.

気中に多数布設する場合の低減率(η_0)(その1)

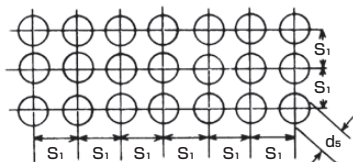
Reduction ratio for multiple wire laying in air (ρ_0) (I)

条数 No. of wires		電流低減率 (η₀) Current reduction ratio (η₀)							
		1	2	3	6	4	6	8	9
配列 Arrangement									
中心間隔 Center distance									
S₁=d₃		0.85	0.80	0.70	0.70	0.60	—	—	—
S₁=2d₃	1.00	0.95	0.95	0.90	0.90	0.90	0.85	0.80	0.80
S₁=3d₃		1.00	1.00	0.95	0.95	0.95	0.90	0.85	0.85

ケーブルを多条布設する場合の許容電流低減率（空中、暗渠）（その2）

Reduction ratio for multiple wire laying in air or duct (ρ_0) (II)

		電流低減率 (η_0) Current reduction ratio (η_0)																
中心配列間隔 Wire center distance	段 Tier (n)	1	2						3									
	列 Row (m)	7 ~ 20	4	5	6	7	8 ~ 20	3	4	5	6	7	8	9 ~ 10	11 ~ 12	13 ~ 15	16 ~ 19	20
S=d ₁		0.70	0.6	0.56	0.53	0.51	0.50	0.48	0.41	0.37	0.34	0.32	0.31	0.30	0.30	0.30	0.30	0.30
S=2d ₂		0.80	—	0.73	0.72	0.71	0.70	—	—	0.68	0.66	0.65	0.65	0.64	0.63	0.62	0.61	0.60



配列は左図に示す例の場合次の様にする。

The arrangement is as shown in the left.

段数 $n=3$

No. of tiers: $n = 3$ 列数 $m=7$

No. of rows: $m = 7$

合計条数は $n \times m = 21$ 条

Total number of wires: $n \times m = 21$ wires

(注) $S=d$ 布数とはケーブル密接布設であり、 $S=2d$ 布設とは互いに隣接するケーブル半径の和の分の空隙をもつ。

(Note) The arrangement $S = d$ corresponds to dense wire laying, while by the arrangement $S = 2d$, the distance between the wires is equivalent to the sum of the radii of adjacent wires.

3. 基底温度 (T_2) が 40°C (又は 30°C) と異なるときは、それぞれの温度に対する補正係数を掛けなければならない。

3. When the base temperature (T_2) is different from 40°C or 30°C, the compensation factor for each temperature must be applied.

基底温度補正係数

Base temperature compensation factor

$$I' = I \times \sqrt{\frac{T_1 - T_2}{T_1 - 40}}$$

I' : 基底温度 T_2 の時の許容電流

: Allowable current at the base temperature of T_2

| : 基底温度 40℃の時の許容電流

: Allowable current for the base temperature of 40°C

T_1 : 導體最高溫度

: Max. conductor temperature

電気特性計算式

Electric characteristics calculation formula

1. 直流導体抵抗

1. DC conductor resistance

$$R = \rho \frac{\ell}{S} = \rho \frac{4\ell}{\pi d^2} (\Omega)$$

$$R_t = R \{1 + \alpha (t - 20)\} (\Omega)$$

ρ : 導体の体積固有抵抗 [$\Omega \cdot \text{cm}$]

: Specific volume resistance of conductor [$\Omega \cdot \text{cm}$]

R : 20℃における直流導体抵抗 [Ω]

: DC conductor resistance at 20℃ [Ω]

R_t : t℃における直流導体抵抗 [Ω]

: DC conductor resistance at t℃ [Ω]

ℓ : 導体長 [cm]

: Conductor length [cm]

d : 導体の直径 [cm]

: Conductor diameter [cm]

S : 導体の断面積 [cm^2]

: Cross-sectional area of conductor [cm^2]

α : 抵抗温度係数

: Temperature coefficient of resistance

σ : 導電率 [%]

: Conductivity [%]

標準軟銅線の断面積 1mm²、長さ 1m での抵抗は、

The DC resistance of a standard annealed copper with a cross-sectional area of 1mm² and length 1m is:

$$R = \frac{1}{58} = 0.017241 (\Omega) \text{ である。}$$

1) 軟銅単線の直流抵抗は

1) The DC resistance of single annealed copper wire is:

$$R = \frac{1}{58} \cdot \frac{4}{\pi d^2} \cdot 1000 = \frac{4 \times 10^3}{58 \pi d^2} (\Omega / \text{km})$$

2) 軟銅撚線の直流抵抗は

2) The DC resistance of annealed copper wire strand is:

$$R = \frac{4 \times 10^3}{58 \cdot \pi d^2 \cdot n} (1 + S)$$

n : 素線数 S : 撚込率 $\begin{cases} 60 \text{ 本以下} & 2\% \\ 60 \text{ 本以上} & 3\% \end{cases}$

where, n is the number of element wire;

S is the lay ratio (2% for n<60, 3% for n≥60)

各種導体材料の基本特性比較表

Basic property of various conductor materials

	比重 (g/cm ³) Specific gravity (g/cm ³)	導電率 (% IACS) Conductivity (% IACS)	固有抵抗 (20℃ μΩ-cm) Specific resistance (20℃ μΩ-cm)	抵抗温度係数 (℃ ⁻¹) Temperature coefficient of resistance (℃ ⁻¹)	線膨張係数 (℃ ⁻¹) Linear expansion coefficient (℃ ⁻¹)
軟銅 Annealed copper	8.89	100	1.7241	0.00393	17.0 × 10 ⁻⁶
硬銅 Hard copper	8.89	97.0	1.7774	0.00381	17.0 × 10 ⁻⁶
耐熱銅 Heat-resistance copper	8.89	96.0	1.7959	0.00381	17.0 × 10 ⁻⁶
珪銅 Silicon copper	8.89	45.0	3.8313	0.00177	17.0 × 10 ⁻⁶
カドミウム銅 Cadmium copper	8.89	85.0	2.0284	0.00334	17.0 × 10 ⁻⁶
40%EF	8.20	39.21	4.3971	0.00381	13.0 × 10 ⁻⁶
30%EF	8.15	29.41	5.8623	0.0038	13.0 × 10 ⁻⁶
硬アルミ Hard aluminum	2.70	61.0	2.8264	0.0040	23.0 × 10 ⁻⁶
イ号アルミ Aldrey wire	2.70	52.0	3.3156	0.0036	23.0 × 10 ⁻⁶
耐熱アルミ Heat-resistant aluminum	2.70	58.0	2.9726	0.0039	23.0 × 10 ⁻⁶
アルモウェルド Almo-weld	6.59	20.3	8.4931	0.0036	13.0 × 10 ⁻⁶
アルミナイズド銅 Aluminized steel	7.55	—	—	—	11.5 × 10 ⁻⁶
亜鉛メッキ鋼 Zn plated steel	7.80	—	—	—	11.5 × 10 ⁻⁶
高導電率耐熱アルミ High-conductivity heat-resistant aluminum	2.70	60.0	2.8735	0.0040	23.0 × 10 ⁻⁶
無酸素銅 Oxygen-free copper	8.94	101	1.710	0.0044	16.5 × 10 ⁻⁶
鉄 Iron	7.86	17.24	10.0	0.006206	11.7 × 10 ⁻⁶
銀 Silver	10.53	105	1.642	0.004074	19.7 × 10 ⁻⁶
金 Gold	19.32	70.7	2.440	0.003968	14.2 × 10 ⁻⁶
錫 Tin	7.29	15.0	11.50	0.00447	23 × 10 ⁻⁶
ニッケル Nickel	8.75	22.1	7.800	0.004873	13.3 × 10 ⁻⁶

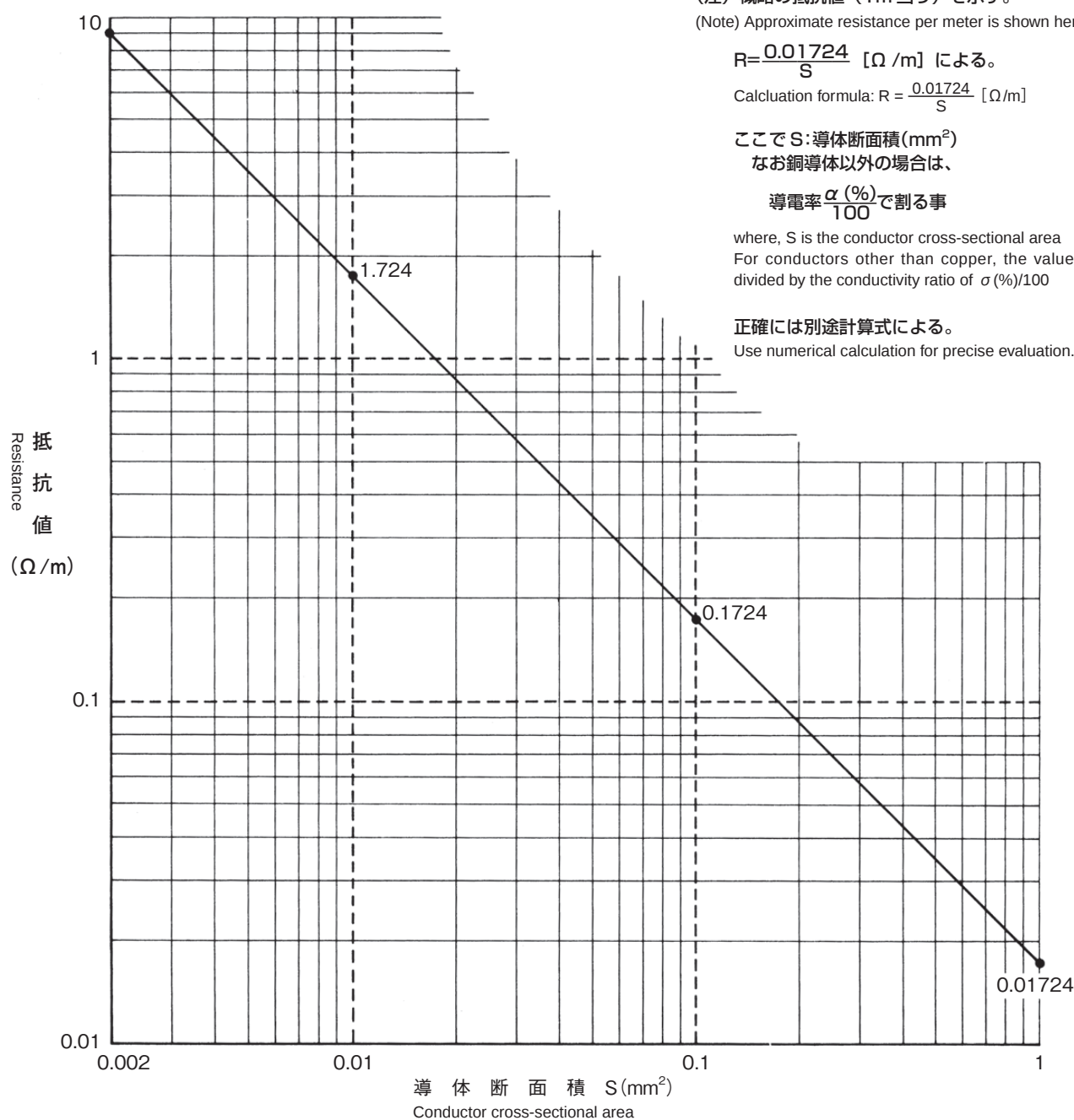
軟銅線の導電率 σ

Conductivity of annealed copper

サイズ Size	軟銅線 Annealed copper wire	錫メッキ軟銅線 Sn plated annealed copper wire
0.08 ~ 0.29 未満 Less than 0.29	0.98	0.93
0.291 ~ 0.45 未満 Less than 0.45	0.993	0.94
0.50 ~ 2.40 未満 Less than 2.40	1.00	0.96

導体抵抗 (銅導体)

Conductor resistance (copper conductor)



2. 絶縁抵抗

2. Insulation resistance

$$R = \frac{3.665}{\ell} \cdot \rho \cdot \log_{10} \frac{D}{d} \times 10^{-7} \text{ (M}\Omega\text{)}$$

R : 絶縁体の絶縁抵抗 [MΩ]

: Insulation resistance of insulator [MΩ]

ρ : 絶縁体の体積固有抵抗 [$\Omega \cdot \text{cm}$]

: Specific volume resistance of insulator [$\Omega \cdot \text{cm}$]

d : 導体外径 [mm]

: Conductor outer diameter [mm]

D : 絶縁体外径 [mm]

: Insulator outer diameter [mm]

ℓ : 電線の条長 [cm]

: Wire length [cm]

絶縁体材料 Insulation material	体積固有抵抗 Specific volume resistance ρ ($\Omega \cdot \text{cm}$)
ビニル (軟質 soft Vinyl 硬質 hard)	$10^{11} \sim 10^{14}$ $> 10^{15}$
ポリエチレン Polyethylene	$> 10^{16}$
架橋ポリエチレン ビーメックス-S Crosslinked polyethylene, BEAMEX-S	$> 10^{16}$
架橋ポリエチレン ビーメックス-ER Crosslinked polyethylene, BEAMEX-ER	$> 10^{15}$
ポリアミド樹脂 Polyamide resin	$4 \times 10^{13} \sim 7 \times 10^{14}$
ETFE	$> 10^{16}$
FEP	$> 10^{17}$
PFA	$> 10^{16}$
PVF ₂	$> 10^{14}$
ポリウレタン Polyurethane	$10^{11} \sim 10^{13}$
ポリエステル Polyester	$10^{14} \sim 10^{15}$
ポリイミド Polyimide	10^{18}
シリコンゴム Silicon rubber	$10^{12} \sim 10^{15}$

絶縁抵抗と外径比の関係

Relationship between insulation resistance and outer diameter ratio

