FORMULAS AND DEFINITIONS

The following formulas and definitions are applied to all applications.

DEFINITION: Resistivity, ρ $\Omega mm^2/m$ (Ω/cmf)

The resistance of a conductor, R_{20}, is directly proportional to its length, L and inversely proportional to its cross-sectional area, q:

$R_{20} = \rho \frac{L}{q}$	Ω	[1]

The proportional constant, ρ is defined as the resistivity of the material and is temperature dependent. The unit of ρ is $\Omega mm^2/m$ (Ω/cmf).

DEFINITION: Temperature factor, C_t

Resistivity or change in resistance with temperature, is non-linear for most resistance heating alloys. Hence, the temperature factor, C_t, is often used instead of temperature coefficient. C_t is defined as the ratio between the resistivity or resistance at some selected temperature T °C and the resistivity or resistance at 20°C (68°F).

$R_T = C_t \cdot R_{20}$	Ω	[2]
$C_t = \frac{R_T}{R_{20}}$		[3]
$C_t = 1 + (T - 20)\,\alpha$ (where T is in °C)		[4]

DEFINITION: Surface load, p W/cm^2 (W/in^2)

The surface load of a heating conductor, p, is its power, P, divided by its surface area, A_C.

$p = \frac{P}{A_C}$	W/cm^2 (W/in^2)	[5]

Wire

$A_C = \pi \cdot d \cdot L \cdot 10$	(metric)	[6]
$A_C = \pi \cdot d \cdot L \cdot 12$	(imperial)	[6]

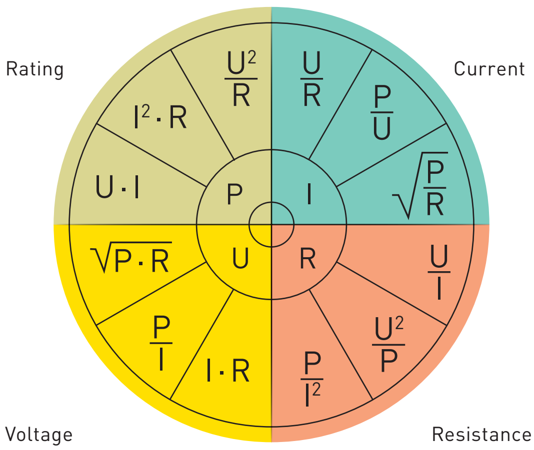
Strip/ribbon

$A_C = 2 \cdot (b + t) \cdot L \cdot 10$	(metric)	[7]
$A_C = 2 \cdot (b + t) \cdot L \cdot 12$	(imperial)	[7]

General formulas

$U = R_T \cdot I$	V	[8]
$P = U \cdot I$	W	[9]

Combining equations [8] and [9] gives:



Combining equations [2], [5], [8] and [9] gives:

$\frac{A_C}{R_{20}} = \frac{I^2 \cdot C_t}{p}$	cm^2/Ω (in^2/Ω)	[10]

The ratio $\frac{A_C}{R_{20}}$, used for determining wire, strip or ribbon size, is tabulated for all alloys in the handbook for 'Resistance heating alloys and systems for industrial furnaces'.

DEFINITION: Cross sectional area, q mm² (in²)

Round wire

$$q = \frac{\pi}{4} \cdot d^2 \qquad \text{mm}^2 \ (\text{in}^2) \quad [11]$$

Combining equations [1], [5], [6] and [11] gives the wire diameter, d:

$$d = \sqrt[3]{\frac{4}{\pi^2} \cdot \frac{\rho \cdot P}{p \cdot R_{20}}} \qquad \text{mm (in)} \quad [12]$$

$$d = \sqrt[3]{\frac{4}{\pi^2} \cdot \frac{\rho \cdot P}{p \cdot R_{20}} \cdot \frac{1}{10}} \qquad \text{(metric)} \quad [12]$$

$$d = \sqrt[3]{\frac{4}{\pi^2} \cdot \frac{\rho \cdot P}{p \cdot R_{20}} \cdot \frac{1}{15.28 \cdot 10^6}} \qquad \text{(imp.)} \quad [12]$$

Example:

ρ = 1.35 Ω mm²/m (812 Ω/cmf) for Kanthal D (according to section 2)
P = 1000 W
p = 8 W/cm² (51.6 W/in²)
R = 40 Ω

According to equation [12]:

$$d = \sqrt[3]{\frac{4}{\pi^2} \cdot \frac{1.35 \cdot 1000}{8 \cdot 40} \cdot \frac{1}{10}} = 0.55 \text{ mm}$$

$$d = \sqrt[3]{\frac{4}{\pi^2} \cdot \frac{812 \cdot 1000}{51.6 \cdot 40} \cdot \frac{1}{15.28 \cdot 10^6}} = 0.022 \text{ in}$$

Strip

$$q = b \cdot t \qquad \text{mm}^2 \ (\text{in}^2) \quad [13]$$

Ribbon

Since ribbons are made by flattening round wires, the cross-sectional area is somewhat smaller depending on size, than equation [13] indicates. As a rule of thumb, a factor 0.92 is used.

$$q = 0.92 \cdot b \cdot t \qquad \text{mm}^2 \ (\text{in}^2) \quad [14]$$

Lately, investigations have shown that a more correct way of expressing the cross-sectional area of ribbon is:

$$q = \left(0.985 - \left(\frac{t}{2 \cdot b}\right)^2\right) \cdot b \cdot t \qquad [14']$$

(Equation [14] is, however, used throughout this handbook).

DEFINITION: Number of turns, n

$$n = \frac{L_e}{s} \qquad [15]$$

DEFINITION: Coil pitch, s mm (in)

A round wire is often wound as a coil. For calculating coil pitch, s, the equation [16] applies:

$$\left(\frac{\pi \cdot (D-d)}{s}\right)^2 + 1 = \left(\frac{L}{L_e}\right)^2 \rightarrow$$

$$s = \frac{\pi \cdot (D-d)}{\sqrt{\left(\frac{L}{L_e}\right)^2 - 1}} \qquad \text{mm} \quad [16]$$

$$s = \frac{\pi \cdot (D-d)}{\sqrt{\left(\frac{L \cdot 1000}{L_e}\right)^2 - 1}} \qquad \text{(metric) } [16']$$

$$s = \frac{\pi \cdot (D-d)}{\sqrt{\left(\frac{L \cdot 12}{L_e}\right)^2 - 1}} \qquad \text{(imperial) } [16']$$

When the pitch, s, is small relatively to coil diameter, D, and wire diameter, d.

Than $\frac{s}{\pi\,(D-d)} \ll L$, so that equation [16] can be simplified to:

$$s = \frac{\pi \cdot (D-d) \cdot L_e}{L} \qquad \text{mm (in)} \quad [17]$$

DEFINITION: Relative pitch, r

The ratio s/d is often used. It is called the relative pitch or the stretch factor, and may affect the heat dissipation from the coil.

$$r = \frac{s}{d} \qquad [18]$$

The ratio D/d is essential for the coiling operation, as well as the mechanical stability of the coil in a hot state.