Example:
Tubular element for a broiler application
Element power rating: 2,000 W (P)
Voltage: 230 V (U)
Final tube diameter 8 mm
Final tube length 1,000 mm

As a first step it is of importance to find out the actual heating zone length.
If the terminal length inside the element tube is 2 × 50 mm the total coil length (L_e) will be:

$$L_e = 1{,}000 - (2 * 50) = 900\ mm$$

Coil hot resistance (R_T) can be calculated using the following equation:

$$R = \frac{U^2}{P} = \frac{230^2}{2{,}000} = 26.45\ \Omega$$

Tube surface load (p_{tube}) can be defined by:

$$P_{y,tube} = \frac{P}{A_{tube}} = \frac{P}{(\pi * d_{tube} * L_e * 0.01)} =$$

$$\frac{2{,}000}{(\pi * 10 * 900 * 0.01)} = 7.07\ W/cm^2$$

For wire surface load (p_{wire}) inside tube, factor 3 is used as general rule of thumb:

$$p_{y,wire} = 3 * p_{y,tube} = 3 * 7.07 = 21.21 \approx 22\ \mathrm{W}/cm^2$$

Wire surface (A_C) can be calculated using the following equation:

$$p_{y,wire} = \frac{P}{A_c} => A_c = \frac{P}{p_{y,wire}} = \frac{2{,}000}{21.21} = 94.29 \approx 94\ cm^2$$

Kanthal's alloy Nikrothal® TE specifically designed for use in tubular elements is an excellent choice for this application and an average wire temperature of 900°C is expected. Due to temperature factor of resistance (Ct = 1,06 for Nikrothal® TE at 900°C) resistance at room temperature can be calculated by using the following equation:

$$R_T = C_t * R_{20} => R_{20} = \frac{R_T}{C_T} = \frac{26.45}{1.06} = 24.95 \approx 25\Omega$$

The ratio between wire surface area and resistance is:

$$\frac{A_c}{R_{20}} = \frac{94}{25} = 3.76\ cm^2/\Omega$$

The value 3.44 (cm2/Ω) for Nikrothal® TE is corresponding to a wire size of about 0.55 mm. We assume that a steel tube of initially 10 mm diameter is being used and can then expect a resistance reduction of about 30 % upon rolling. The resistance of the coil should therefore be close to 35 Ω.

The wire surface prior to compression is normally up to 7 % bigger, or 100 cm^2, and the ratio between wire surface and resistance 2.85 cm^2/Ω. The corresponding wire size is 0.50 mm.

Performing tests using calculated wire size is recommended aiming to verify element properties and influence from both coiling and reduction as a result of compression.

Example:
Suspended coil element for convection heater
Element power rating: 3,000 W (P)
Voltage: 230 V (U)
Coil length: 850 mm (L_e)

For a suspended element in a forced convection application the recommended wire surface load is normally ranging from 7 to 8 W/cm^2. For this element calculation example a suitable surface load at 8 W/cm^2 will be used.

The first thing to calculate is the total wire resistance needed. This is done in two steps by using the following calculations:

1. Coil hot resistance (R_T):

$$R = \frac{U^2}{P} = \frac{230^2}{300} = 17.63\ \Omega$$

Coil resistance at room temperature can be calculated by dividing the hot resistance (R_T) using the temperature factor (C_t). For this application design Nikrothal® 60 is a well proven alloy and at the expected temperature level 900°C the defined Ct value is 1.10.

2. Coil cold resistance (R_{20}):

$$R_{20} = \frac{R_T}{C_T} = \frac{17.63}{1.10} = 16.03\Omega$$

Wire surface area (A_C) is given by dividing element Power with the wire surface load:
$A_C = P / p = 3{,}000 / 8 = 375\ cm^2$

By using the result from surface area calculation, a suitable wire dimension can be found by calculating the surface area to cold resistance ratio, resistivity at room temperature (cm^2/Ω).

The ratio between wire surface and resistance is:

$$R_{20} = \frac{R_T}{C_T} = \frac{17.63}{1.10} = 16.03\Omega$$

Comparing the calculated value for resistivity at room temperature (cm^2/Ω) in the table for Nikrtohal® 60 shows that wire dimension Ø 1.0 mm is the closest match at 22.2 cm^2/Ω.

When wire dimension has been set the information on resistance per meter wire (Ω/m) is available from the Nikrothal® 60 table, hence total wire length can be calculated:

$$\frac{A_c}{R_{20}} = \frac{375}{16.03} = 23.39\ cm^2/\Omega$$

Wire surface load with selected wire dimension Ø 1.0 mm can be verified by the following calculation, as value surface area per meter (cm2/m) can be found in the Nikrothal® 60 table:

$$p_{y,wire} = \frac{P}{(cm^2/m) * L} = \frac{3{,}000}{31.4 * 11.6} = 8.21\ W/cm^2$$

The ratio between coil diameter and wire diameter (D/d) depends greatly on element design and wire temperature. For suspended element in this calculation outer coil diameter 15 mm is selected. This gives the following ratio:

$$\frac{D}{d} = \frac{15}{1} = 15$$

Coil pitch (s) can be found by using equation:

$$s = \frac{\pi * (D - d) * L_e}{L} = \frac{\pi * (15 - 1) * 850}{11.63} = 3.21mm$$

Use the following calculation to find out the number of element coil turns (W):

$$W = \frac{(1{,}000 * L)}{\pi * (D - d)} = \frac{(1{,}000 * 11.63)}{\pi * (15 - 1)} = 264\ turns$$

Close wound coil length (Lw) is given by number of coil turns times wire dimension:

$$L_w = W * d = 264 * 1 = 264$$

The streched coil length (Le) can now be calculated:

$$L = \frac{s}{d} * L_w = \frac{3.21}{1} * 264 = 847\ mm$$

Application tests to adjust and verify appropriate air flow settings is recommended and should always be considered in order to confirm element coil calculation and heating element properties in forced convection.