The main steps of computing the electrical power P, which is the dissipated thermal power, needed to reach the objective temperature, are briefly reported here.

$$P = \dot{Q}_{Conv} + \dot{Q}_{irr} = hA_s(T_{max} - T_\infty) + \sigma\varepsilon A_s(T_{max}^4 - T_\infty^4) \quad (1)$$

Eq. (1) denotes how the present application represents the typical case of a natural convection heat transfer mechanism (represented by the corresponding thermal power $\dot{Q}_{Conv}$) combined with the radiative one (expressed by the thermal power $\dot{Q}_{irr}$). The convective and radiative heat exchange mechanisms between the specimen at the temperature T_{max} (to be reached) and the surrounding air at the temperature T_∞, involves the following terms:

h = convective heat transfer coefficient [W/m^{2}K]
A_{se} = exposed heat exchange surface of the specimen [m^2]
T_{max} = specimen temperature to be reached [K]
T_∞ = surrounding ambient temperature [K]
ε = emissivity of the wire
σ = 5.67*10^{-8} is the Stefan-Boltzmann constant [W/m^{2}K^4]

The present thermal-fluid dynamic problem is under the typical category of a "horizontal hot plate with the surface facing up". The next step is calculating the characteristic length L_c Eq. (2):

$$L_C = \frac{A_{se}}{p} \quad (2)$$

where A_{se} is the exposed heat transfer surface of the specimen and p is its perimeter. The Rayleigh number Ra_{Lc} based on the characteristic length has to be computed as follows Eq. (3):

$$Ra_{L_C} = \frac{\beta g(T_{max} - T_\infty)L_C^3 Pr}{\nu^2} \quad (3)$$

where:
β = thermal expansion coefficient at constant pressure [1/K]
g: gravitational acceleration [m/s^2]
Pr= Prandtl number
ν= cinematic viscosity [m^2/s]

The quantities in Eq (3) are evaluated at the film mean temperature T_{film} defined as Eq. (4):

$$T_{film} = \frac{T_{max} + T_\infty}{2} \quad (4)$$

It enables the possibility to evaluate the thermal expansion coefficient at constant pressure Eq. (5) and the Prandtl number Eq. (6):

$$\beta = \frac{1}{T_{film}} \quad (5)$$

$$\mathrm{Pr} = \frac{\nu}{\alpha} \quad (6)$$

where α is the thermal diffusivity [m^2/s] at the temperature T_{film}.

To evaluate the convective heat coefficient *h* in Eq. (1) the Nusselt number Nu_{Lc} based on the characteristic length has to be evaluated according to the Eq. (7) and Eq. (8) depending on the estimated Ra value:

$$Nu_{L_C} = 0.54\, Ra^{1/4} \tag{7}$$

Eq. (7) applies in case 10^4<Ra<10^7 (i.e. the convective fluid flow regime is laminar).

$$Nu_{L_C} = 0.13\, Ra^{1/3} \tag{8}$$

Eq. (8) applies in case 10^7<Ra<10^{11} (i.e. the convective fluid flow regime is turbulent).

Then the convective heat transfer coefficient *h* in Eq. (1) is obtained using Eq.(9):

$$h = Nu_{L_C} \frac{k}{L_C} \tag{9}$$

where k is the thermal conductivity of the ambient air evaluated at the temperature T_{film} [W/mK].

Finally, once evaluated P, the values of electrical resistance and electrical power are central to obtaining the output values of current and voltage to apply. The calculation of electrical resistance (Eq. 10) provides:

$$R = \frac{L_{tot}\, \rho\, 10^{-2}}{s\, 10^{-6}} \tag{10}$$

where:
L_{tot} = total length [m]
ρ = resistivity of the conductive wire [Ω cm]
s = cross-sectional area of the wire [mm^2]

With these quantities, it is possible to determine the value of the electric current, Eq. (11):

$$I = \sqrt{\frac{P}{R}} \tag{11}$$

Thanks to the value of the current, it is then possible to calculate the voltage, Eq. (12):

$$V = \frac{P}{I} \tag{12}$$