(1) It is easiest to carry out calculations for a nominal 1 m tube length and then to scale the results.

$L_x = 0{\cdot}42\,m$ $\qquad$ $L_y = 0{\cdot}85\,m$

$d = 0{\cdot}0004\,m$ $\qquad$ $b = 0{\cdot}053\,m$

$k = 200\ W/mK$ $\qquad$ $h_1 = 525\ W/m^2K$

$h_2 = 23\ W/m^2K$ $\qquad$ $N_p = 120$

$L_p = 1\,m$ $\qquad$ $d_o = 0{\cdot}0215\,m$

$N_s = 1/0{\cdot}00635 = 157$ $\qquad$ $x = 0{\cdot}00175\,m$

$$A_p = \pi \times 0{\cdot}0215 \times 120 \times (1 - 157 \times 0{\cdot}0004) = 7{\cdot}60\,m^2$$

$$A_s = 2 \times 157 \times \left(0{\cdot}85 \times 0{\cdot}42 - 120\tfrac{\pi}{4} \times 0{\cdot}0215^2\right) = 98{\cdot}4\,m^2$$

Triangular pitch $\quad H = (0{\cdot}95 \times 0{\cdot}053 - 0{\cdot}0215)/2$

$$= 0{\cdot}0144\,m$$

$$1 + 2H/d_o = 1 + 2 \times 0{\cdot}0144/0{\cdot}0215 = 2{\cdot}34$$

$$H\sqrt{2h_2/dk} = 0{\cdot}0144\,(2 \times 23/0{\cdot}0004/200)^{0{\cdot}5} = 0{\cdot}345$$

From Fig 2 $\quad \eta_f = 0{\cdot}96$

$$A_1 = 120\,\pi\,0{\cdot}018 = 6{\cdot}79\,m^2$$

$$\frac{1}{UA} = \frac{1}{525 \times 6{\cdot}79} + \frac{0{\cdot}00175}{200 \times 6{\cdot}79} + \frac{1}{23(7{\cdot}6 + 0{\cdot}96 \times 98{\cdot}4)}$$

$$= 2{\cdot}805 \times 10^{-4} + 1{\cdot}2 \times 10^{-6} + 4{\cdot}07 \times 10^{-4}$$

$$= 6{\cdot}88 \times 10^{-4}\ K/W$$

$$UA = 1453\ W/K$$

Now air flow $= (0{\cdot}85 \times 1 \times 3{\cdot}1) = 2{\cdot}635\ m^3/s$

At 23°C $\quad \rho = 1{\cdot}18\ kg/m^3$ (approx)

$$m = 2{\cdot}635 \times 1{\cdot}18 = 3{\cdot}11\ kg/s$$

$$\phi = 1453\,\Delta\theta_m = 3{\cdot}11 \times 1010 \times (\theta_{off} - 23)$$

$$\Delta\theta_m = [15 - (38 - \theta_{off})] / \ln[15/(38 - \theta_{off})]$$

Simultaneous solution is required. $\Delta\theta_m$ must be less than 15 K so $\phi < 1453 \times 15 = 21795\,W$, Hence $\theta_{off} < 29{\cdot}9$°C

Try $\phi = 19000\,W \Rightarrow \Delta\theta_m = 13{\cdot}1\,K$ and $\theta_{off} = 29{\cdot}0$°C