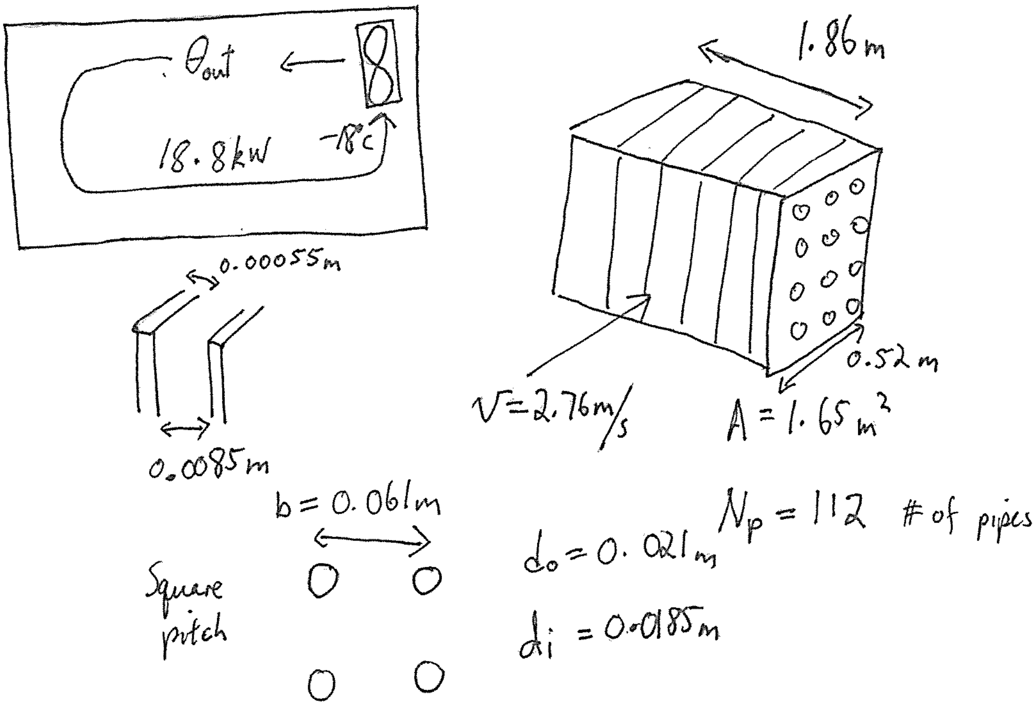
## 3.3 WORKED EXAMPLE – AIR FIN HEAT EXCHANGERS

A coldstore is being built – the expected heat load to be removed is 18.8 kW at an air temperature onto the evaporator of –18°C. An old air cooling unit is available – it has a face area of 1.65m$^2$, and the fan maintains an air flow of 2.76 m/s off this face. The unit has aluminium fins (k = 200 W/mK) of thickness 0.55mm and spaced at 8.5mm centres. The unit length is 1.86m, and its depth in the direction of air flow 0.52m. the film heat transfer coefficient in the boiling refrigerant has been estimated as 265 W/m2K, and that in the air flow as 19 W/m2K. There are 112 tubes of outside diameter 21 mm and inside diameter 18.5mm, these being placed in square pitch at 61mm centres. Determine the refrigerant evaporation temperature required if the unit is to accomplish the required heat transfer.

### 3.3.1 Scenario diagram




### 3.3.2 Calculate the air off temperature

$$\text{Air flow rate} = 2.76\ m/s \times 1.65\ m^2$$
$$= 4.55\ m^3/s$$

At $-18°C$ $\rho = 1.38\ \frac{kg}{m^3}$ density of air

$$\dot{m}_{air} = 4.55 \times 1.38$$
$$= 6.28\ kg/s$$

$$\phi = \dot{m} C_p \Delta\theta = \dot{m} C_p (-18 - \theta_{out})$$
$$18.8 = 6.28\,(1.01)\,(-18 - \theta_{out})$$
$$\theta_{out} = -21°C$$

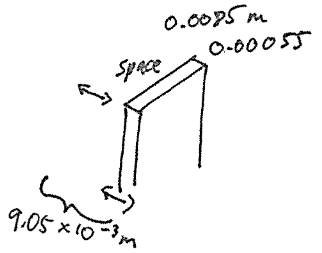
### 3.3.3 Calculation of the UA value

$$\frac{1}{UA} = \frac{1}{h_1 A_1} + \frac{x}{KA_{12}} + \frac{1}{h_2(A_p + \eta_f A_f)}$$

$$A_p = \pi d_o N_p (L_p - N d)$$
area of plates

$$N = \frac{1.86}{9.05\times10^{-3}} + 1 = 206 \text{ fins}$$
# of fins

$$L_x = \frac{1.65}{1.86} = 0.887\,m$$




$$A_p = \pi \times 0.021 \times 112\,[1.86 - 206 \times 0.00055]$$
$$= 12.91\ m^2$$

$$Af_{ins} = 2N\left(L_x L_y - N_p \frac{\pi}{4} d_o^2\right)$$

$$= 2 \times 206\left(0.89 \times 0.52 - 112\frac{\pi}{4} \times 0.021^2\right)$$

$$= 174.7\ m^2$$

To find $\eta_f$:

$b = 0.061$

Square pitch tubes

$$H = \left(\frac{1.13b - 0.021}{2}\right) = \frac{1.13 \times 0.061 - 0.021}{2}$$
$$= 0.024\,m$$

$$Z_1 = H\sqrt{\frac{2h_2}{dk}} = 0.024 \times \sqrt{\frac{2(19)}{0.00055 \times 200}}$$
$$= 0.446$$

$$Z_2 = 1 + \frac{2H}{d_o}$$
$$= 1 + \frac{2 \times 0.024}{0.021} = 3.29$$

from figure 26

$$\therefore \eta_f = 0.89$$

$$A_1 = N_p \pi d_i L$$ inside diameter

$$= 112 \times \pi \times 0.0185 (1.86)$$

$$= 12.1\ m^2$$

$$A_{12} = 2\pi \left( \frac{\overset{r_2}{9.25 \times 10^{-3}} + \overset{r_1}{0.0105}}{2} \right) LN$$

$$= 2\pi (9.875 \times 10^{-3})\, 1.86 (112)$$

$$= 12.92\ m^2$$

$$x = \text{pipe thickness} = \frac{1}{2}(0.021 - 0.0185)$$

$$= 0.00125\ m$$

$$\frac{1}{UA} = \frac{1}{265(12.1)} + \frac{0.00125}{200(12.92)} + \frac{1}{19(12.91 + 0.89 \times 174.7)}$$

$$= 3.1187 \times 10^{-4} + 4.84 \times 10^{-7} + 3.125 \times 10^{-4}$$

$$UA = 1600\ \frac{W}{K}$$

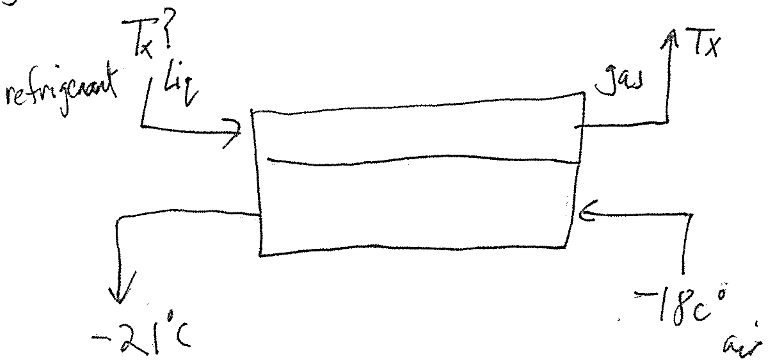
### 3.3.4 Calculate the required evaporation temperature

$$\phi = UA\, F_t\, \theta_{LMTD}$$ assume $F_t = 1$ (fully counter current)

$$-18.8 = 1.6\, \Delta\theta_{LMTD}$$

negative because it is being cooled

$$\Delta\theta_{LMTD} = -11.75\ ^\circ C$$




$$\Delta\theta_{LMTD} = -11.75^\circ C$$

Iterate for $T_x$

$$\frac{[T_x - (-21)] - [T_x - (-18)]}{\ln \left[ \dfrac{T_x - (-21)}{T_x - (-18)} \right]} = -11.75^\circ C$$

$T_x = \underline{\underline{-31.3^\circ C}}$ after some iterations.