Homework no. 3

Design water-water tube-in-tube heat exchanger build for required thermal output 90 kW.

- Heating/cooled water has mass flow rate m_1 = 0,9 kg/s and inlet temperature t_{11} = 80 °C
- heated water has flow rate m_2 = 0,8 kg/s
- heated water has inlet temperature t_{21} = 15 °C and required outlet temperature t_{22} = 55 °C

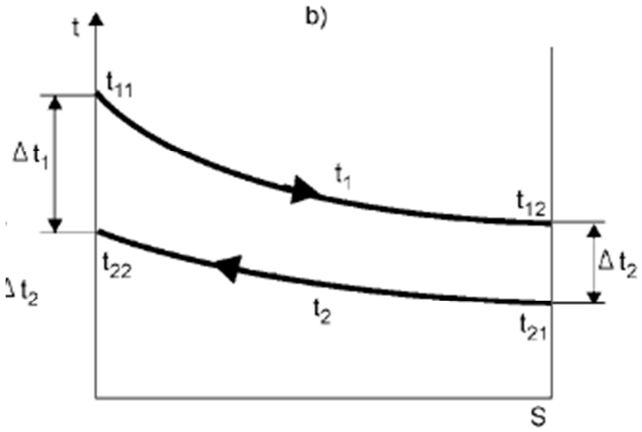
Heating water flows inside inner tube, heated water flows within annulus. Both flows are in counter-current arrangement.

Goals:

- design of required heat exchanging surface
- design of heat exchanger basic shape (length, tubes diameters, etc.)

Supporting info:

Mean logarithmic temperature difference:



$$\overline{\Delta t_p} = \frac{\Delta t_2 - \Delta t_1}{\ln \frac{\Delta t_2}{\Delta t_1}} = \frac{(t_{12} - t_{21}) - (t_{11} - t_{22})}{\ln \frac{t_{12} - t_{21}}{t_{11} - t_{22}}}$$

Criteria equation:

a) Convection on inner surface of inner tube

$$Nu = 0{,}021 . Re^{0,8} \, Pr^{1/3} \left(\frac{\bar{\eta}}{\eta_s} \right)^{0.14} \quad ; \quad \text{for } 0{,}7 < Pr < 120 \text{ and } 10^4 < Re < 10^5$$

b) Convection on outer surface of inner tube

$$Nu = 0{,}021 \, (r_e/R_i)^{0,45} \, Re^{0,8} \, Pr^{1/3} \left(\frac{\bar{\eta}}{\eta_s} \right)^{0.14}$$; where Re and Nu is calculated for width $B = 2(r_e - R_i)$

Calculation of convection heat transfer coefficient from Nusselt number:

$$\alpha_1 = \frac{Nu \cdot \lambda}{D}$$

Calculation of total heat transmission coefficient:

$$U = \frac{2\pi}{\frac{1}{\alpha_1 \cdot r_1} + \frac{1}{\lambda_{oc}} \ln\frac{r_2}{r_1} + \frac{1}{\alpha_2 \cdot r_2}}$$

Chart of physical characteristics of water:

Temperature t **[°C]**	**Density** ρ **[kg·m^{-3}]**	**Heat capacity** c_p **[J·kg^{-1}·K^{-1}]**	**Thermal conductivity** λ **[W·m^{-1}·K^{-1}]**	**Temperature conductivity** a **[J·kg^{-1}·K^{-1}]**	**Thermal expansivity** $\gamma \cdot 10^3$ **[K^{-1}]**	**Dynamic viskozity** $\eta \cdot 10^{-6}$ **[Pa·s]**	**Kinematic viskozity** $\nu \cdot 10^{-6}$ **[m^2·s^{-1}]**	**Prandtl number** Pr **[-]**
0	999,8	4,25	0,552	0,131	-0,063	1790	1,790	13,70
10	999,6	4,22	0,575	0,136	0,088	1300	1,300	9,56
20	998,2	4,21	0,598	0,142	0,207	1000	1,000	7,06
30	995,6	4,20	0,617	0,147	0,304	802	0,805	5,50
40	992,2	4,20	0,634	0,152	0,390	653	0,659	4,30
50	988,0	4,20	0,648	0,156	0,460	549	0,556	3,56
60	983,2	4,21	0,659	0,159	0,530	461	0,479	3,00
70	977,7	4,22	0,668	0,162	0,580	404	0,415	2,56
80	971,8	4,23	0,675	0,164	0,630	356	0,366	2,23
90	965,3	4,24	0,680	0,166	0,700	315	0,326	1,95